Investigating the Effectiveness of a Gymnastics Intervention on Motor skills and Balance of Children ages 5-9 with Autism Spectrum Disorder

By

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Investigating the Effectiveness of a Gymnastics Intervention on Motor skills and Balance of Children ages 5-9 with Autism Spectrum Disorder

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Abstract

Children with Autism Spectrum Disorder (ASD) usually display motor skills and balance that are delayed and less proficient compared to their peers with typical development (TD). However, very little research has focused on implementing interventions targeting motor skills and balance of children with ASD. The purpose of this study was to examine the effectiveness of a gymnastics intervention on motor skills and balance of children ages 5-9 with ASD compared to a fine motor intervention. Participants were randomly assigned into the gymnastics or fine motor group. The results indicated that overall motor skills, as well as motor skill subtests and subscales slightly improved for both groups following the intervention. In addition, manual dexterity significantly improved for the fine motor group following the intervention (p=0.03). The results also indicated small improvements in some sections of the balance assessment for both groups following the intervention. The results of this study indicate that a six-week gymnastics intervention, once a week for 45 minutes per session, did not lead to a significant improvement in motor skills or balance of children ages 5-9 with ASD. More research is needed on the effect of gymnastics interventions with a higher dosage and intensity, as well as a larger sample size.

Keywords: autism spectrum disorder, motor skills, balance, gymnastics, motor skill interventions

Statement of Originality

I, Shahrzad Pezhman, hereby declare that this thesis is, to the best of my knowledge, original, except as acknowledged in the text. I further declare that the material contained in this thesis has not been previously submitted, either in whole or in part, for a degree at this or any other university.

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I would like to dedicate this study to my grandfather who always supported me throughout the different stages of my life. He left us in the fall of 2016, but his love will always be a source of encouragement for me.

List of Abbreviations Used

ADHD	Attention Deficit/Hyperactivity Disorder
ASD	Autism Spectrum Disorder
BOTMP	Bruininks-Oseretsky Test of Motor Proficiency
BOT-2	Bruininks-Oseretsky Test of Motor Proficiency, Second Edition
DSM	Diagnostic and Statistical Manual of Mental Disorders
HFA	High Functioning Autism
ICF	International Classification of Functioning, Disability and Health
MABC	Movement Assessment Battery for Children
MABC-2	Movement Assessment Battery for Children, Second Edition
MSEL	Mullen Scales of Early Learning
PDDNOS	Pervasive Developmental Disorder - Not Otherwise Specified
SDHRP	Simulated Developmental Horse-Riding Program
TD	Typical Development
WHO	World Health Organization

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Overview

This thesis is divided into five sections:

1. Introduction
2. Literature Review
3. Manuscript
4. Thesis Conclusions
5. Appendices that include ethics approval, consent forms, child assent form, recruitment flyer, social media blurb, and supplemental information form

Chapter 1: Introduction

Autism Spectrum Disorder and Motor Skills

Autism Spectrum Disorder (ASD) is a neurodevelopmental disability which is characterized by deficits in social communication, social interactions, as well as restricted and repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013). The prevalence of ASD has shifted from approximately 6.6 cases per 10,000 in the 1980s (Gillberg, 1990), to its current estimate of 1 case per 45 births (Zablotsky, Black, Maenner, Schieve, & Blumberg, 2015).

Compared to previous estimates, there are currently a larger number of children being diagnosed with ASD, and considering the challenges faced by these children, there is a need to conduct interventions to reduce the difficulties they experience. These interventions include motor skill interventions, physical therapy, occupational therapy, and behavioural therapy (Bremer, Balogh, & Lloyd, 2015; Myers & Johnson, 2007).

Studies have shown that in addition to the three core symptoms of ASD, children with ASD demonstrate deficits in other areas of development. One of these impairments, known as an associated symptom, is poor motor skills (Liu & Breslin, 2013; Lloyd, MacDonald, & Lord, 2013; Ozonoff et al., 2008; Provost, Lopez, & Heimerl, 2007; Staples & Reid, 2010; Whyatt & Craig, 2012). Infants with ASD have been found to experience challenges in reaching motor milestones, and evidence indicates that they are delayed developmentally compared to children with typical development (TD) (Landa & Garrett-Mayer, 2006). Moreover, motor skills of children with ASD usually become significantly worse as they get older (Landa & Garrett-Mayer, 2006; Lloyd et al., 2013). During childhood, children use their motor skills to explore the environment, perform daily activities, initiate social interactions, engage in play and physical activity, and develop basic academic skills (Gibson, 2000), which are all important for an optimal development and a healthy lifestyle (Bhat, Galloway, & Landa, 2012; Pan, 2010). All these developmental areas can be affected by the poor motor skills of children with ASD. Research has shown that children with ASD can improve motor skills through motor skill interventions (Bremer, Balogh, & Lloyd, 2015; Yilmaz, Yanardağ, Birkan, & Bumin, 2004). However, these interventions require more focus in comparison to the other areas of development (Jasmin et al., 2009). Given the importance of motor skills for children with ASD, there is a need to conduct motor skill interventions aiming to improve motor proficiency in children with ASD.

Balance

In addition to motor skill difficulties, children with ASD have been reported to have impairments in balance and postural control (Memari, Ghanouni, Shayestehfar, & Ghaheri, 2014; Minshew, Sung, Jones, & Furman, 2004). As balance and postural control are essential requirements in achieving motor skills for children (Arzoglou et al., 2013), impairments in balance and postural control can affect the motor development of children (Fabbri-Destro, Gizzonio, & Avanzini, 2013). Moreover, impairment in balance often acts as the limiting factor in the ability of the children to engage in activities at home, school, and during play (Silkwood-Sherer, Killian, Long, & Martin, 2012). Therefore, it is essential to conduct interventions targeting to improve balance in children with ASD.

Gymnastics

Gymnastics is a sport that can help individuals to develop kinesthetic awareness and to move the body more efficiently in everyday life, as well as to help children develop basic motor skills (Baumgarten & Pagnano-Richardson, 2010; Donham-Foutch, 2007). There are additional benefits for children in participating in gymnastics, such as helping to develop better coordination, body awareness, balance, and body posture, as well as better flexibility, strength, and agility (Carrick, Oggero, Pagnacco, Brock, & Arikan, 2007; Donham-Foutch, 2007; Fotiadou et al., 2002; Zetaruk, 2000).

Among 200,000 individuals registered in gymnastics in Canada, over 90% are engaged in recreational gymnastics (Gymnastics Canada Gymnastique, 2008). Recreational gymnastics can help children with spatial and body awareness, muscle strength, neuromuscular coordination, balance, and flexibility development (Gruodyte-Raciene, Erlandson, Jackowski, & Baxter-Jones, 2013). In this type of gymnastics, participants work on movement patterns such as walking, jumping, hopping, and running. In contrast with competitive gymnastic, participants do not require to have high levels of experience, therefore, it is possible to teach recreational gymnastics easily to children with any levels of ability (Kurnik, Kajtna, Bedenik, & Kovač, 2013).

Previous research has suggested that gymnastics interventions can be effective at improving motor skills of individuals with disabilities (Fotiadou et al., 2009; Moraru, Hodorca, & Vasilescu, 2014). Given the importance of motor skills proficiency for children with ASD (Bhat, Galloway, & Landa, 2012; Jasmin et al., 2009; MacDonald, Lord, &

Ulrich, 2013), it is important that future research determine the effect of gymnastics interventions for this population.

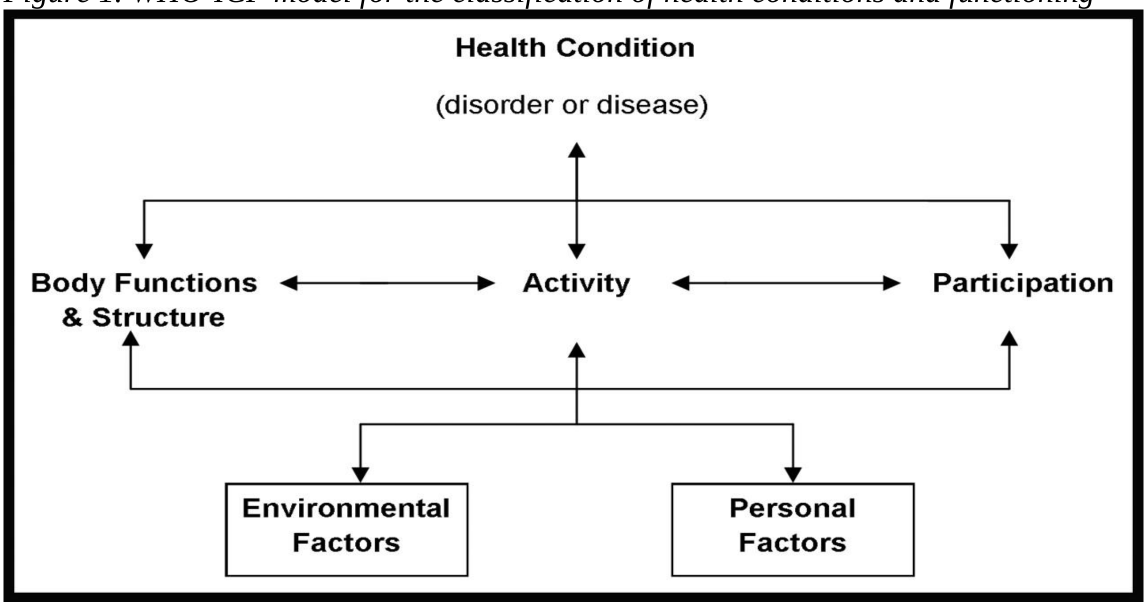
Proposed Research Framework: World Health Organization – International Classification of Functioning, Disability and Health (WHO-ICF)

The International Classification of Functioning, Disability and Health (ICF) was developed and published by the World Health Organization (WHO) in 2001. WHO-ICF aims to provide a standard description of health and health-related conditions at both individual and population levels (WHO, 2001). Since 2001, some changes have been applied to the new version of WHO-ICF compared to the previous one. The changes replaced the WHO's original classification in 1980 which focused on the limitation of people as the main determinant for disability. Whereas in the current version, the ICF demonstrates a broader view of the concepts of health and disability, and explains disability as a term that every human being may experience some degree of in their life through a change in the environment or health (WHO, 2001). Therefore, according to WHO-ICF disability is not restricted to only a small part of the population. The ICF model is designed to provide scientific basis for understanding health-related states and outcomes, to establish a common language describing health and health-related states, and to develop the conception that mind, body, and environment are not separable. The ICF model suggests that disability is the variation of human functioning and is caused by one or a combination of the following factors: the loss or abnormality of a body part and difficulties an individual may have in executing activities (Flatters et al., 2014). In the ICF model, functioning and disability are related to: 1. Body function and structure which refers to the actual anatomy and physiology/psychology of the human body, 2. Activity and participation. Activity refers to the activities performed at the level of the individual, and the activity limitation they experience, whereas the participation is related to the functioning of the person as a member of the society in a real life situation. 3. Personal and environment factors. In conclusion, the functioning of an individual reflects an interaction between health condition, personal, and environmental factors in this model (WHO, 2001).

Children with ASD, Gymnastics Intervention, and ICF

Figure 1 shows the WHO-ICF model that was applied in this study.

Figure 1. WHO-ICF model for the classification of health conditions and functioning



Health Condition

All of the participants for this study have a diagnosis of ASD and therefore demonstrate impairments in social skills and communication, along with stereotyped behaviour and restricted interests, behaviour, or activities. Due to the safety issues, children with aggressive or self-injurious behaviour were excluded from the study.

Body Function and Structure

Body function and structure describe the actual anatomy and physiology of the human body. There is no significant difference between body function and structure between children with ASD and TD. However, many children with ASD have a diagnosis of intellectual disability (American Psychiatric Association, 2013; Matson & Smith, 2008).

Activity

Activity refers to the execution of an action by the individual and the tasks that the individual is able to perform. It includes communication, mobility, learning, etc. The activities may be limited because of poor motor skills and balance in children with ASD. A Gymnastics intervention may improve motor skills and balance. The intervention focused on motor skills such as jumping, running, rolling, as well as balance and strength activities. It is hopeful that improvements in motor skills and balance can further result in more participation in recreational activities, play, and improvement in social skills and daily activities, thus affecting the children's overall development. In order to identify any changes to motor skills of the children, the Bruininks-Oseretsky Test of Motor Proficiency second edition (BOT-2) was applied, and to assess balance, balance sections of Movement

Assessment Battery for Children, Second Edition (MABC-2) were used before and after the intervention, following with another assessment four weeks after the intervention.

Participation

Participation is defined as the involvement of the child in a real life situation and using his/her ‘activity’ level skills to interact. By performing different motor skills during this intervention, it is hoped that the participants will be interested in performing more motor skills and physical activities. The skills will become largely permanent when performed regularly, which can finally cause an improvement in ‘activity’ level of the participants.

Environmental Factors

Environmental factors have an impact on all components of functioning and disability, and can include different settings that influence the process of learning in the child. The environment plays a role in making the activity interesting for children with ASD. For instance, the children were given the option to choose equipment based on their favourite colour. Moreover, it is beneficial for the children to be in an environment that has been modified to their needs as it may have an influence on their learning process. For instance, since children with ASD experience sensory issues, having too many children and loud noises in the room while the intervention was running.

Personal Factors

Personal factors can include social backgrounds, race/ethnicity, education, and sex. In contrast with the environmental factors, we cannot usually modify personal factors.

Participants in this study can come from different social backgrounds, and lifestyles. In addition, both girls and boys can participate in the study.

Significance of the Study: Addressing the Gaps in the Literature

This study will add to the scientific literature regarding motor skills of children with ASD. It will address the gaps in the literature regarding interventions on the motor skills of this population. Although children with ASD have consistently been reported to experience deficits in motor skills (Jasmin et al., 2009; Liu & Breslin, 2013; Staples & Reid, 2010; Whyatt & Craig, 2012), previous research has mainly focused on the core characteristics of ASD, and motor skill interventions have been neglected in this population. There have only been a limited number of studies that looked at the effectiveness of motor skill interventions on children with ASD (Bremer et al., 2015; Huettig & Darden-Melton, 2004; Yilmaz, Yanardağ, Birkan, & Bumin, 2004). This study will aim to improve motor skills and balance of children with ASD by teaching the children various motor skills and balance activities through a gymnastics intervention.

Purpose and Overall Contribution

The overall purpose of this study is to examine whether there will be benefits to children ages 5-9 with ASD in regards to motor skills following a gymnastics intervention compared to a fine motor intervention. The secondary purpose is to evaluate the effectiveness of a gymnastics intervention on balance of children ages 5-9 with ASD, compared to a fine motor intervention. It is important to improve motor skills in children with ASD as motor skills are essential for engaging in domains such as leisure and daily living activities, as well as play. Currently there is no research supporting the effectiveness of a gymnastics intervention for children ages 5-9 with ASD, therefore, findings from this study will fill a gap in the scientific literature, and can help shape future motor skill interventions for children with ASD.

Hypothesis and Objectives

Objectives of Research

1. To investigate the effect of a gymnastics intervention on motor skills of children ages 5-9 with ASD and compare it with a fine motor intervention.

2. To investigate the effect of a gymnastics intervention on balance of children ages 5-9 with ASD and compare it with a fine motor intervention.

Specific Hypothesis of the Research

1. The gymnastics intervention will result in improvements to the motor skills of children ages 5-9 with ASD.

2. The gymnastics intervention will results in improvements to the balance of children ages 5-9 with ASD.

3. The fine motor intervention will result in improvements to the fine motor skills of children ages 5-9 with ASD

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Chapter 2: Literature Review

Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a neurodevelopmental disability (Jones & Lord, 2013) which was first described by psychiatrist Leo Kanner in 1943 (Kanner, 1943). Kanner published a report “Autistic Disturbances of Affective Contact”, describing 11 children who had similar characteristics such as inability to relate to themselves, being happiest when left alone, having severe communication problems, and high intelligence. He also described the children’s behaviour as having an anxiously obsessive desire to maintain sameness. Although the children were physically healthy, some of them were clumsy in their gait and gross motor performance (Kanner, 1943). In 1944 the German pediatrician Hans Asperger described a group of four children between the ages of 6 and 11 who had impairments in social interactions, peculiarities of communication, obsession for doing things their own way that prevented them from learning, and having narrow interests (Frith & Mira, 1992). American Psychiatric Association published the Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (DSM-IV) in 2000, in which they listed five Pervasive Developmental Disorders under Autism Spectrum Disorders (American Psychiatric Association, 2000). The disorders included: Autistic Disorder, Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS), Asperger syndrome, Rett’s Disorder, and Childhood Disintegrative Disorder. According to DSM-IV, the key defining symptoms of Autism Spectrum Disorders were impairments in social interactions and communication, along with the existence of a range of repetitive behaviour, interests, or activities (American Psychiatric Association, 2000). The current diagnostic criteria (DSM-V) uses the umbrella term ASD for children who show persistent deficits in social communication and social interaction, as well as demonstrating restricted and repetitive patterns of behaviour, interests, or activities. The symptoms must be present in early childhood and limit and impair everyday functioning. Moreover, the disturbances should not be better explained by intellectual disability or developmental delays (American Psychiatric Association, 2013).

The prevalence of ASD has changed from 6.6 per 10,000 in the 1980s (Gillberg, 1990) to 1 in 150 (Fombonne, 2009) and 1 in 88 cases (Kogan et al., 2009). The current estimate of ASD is 1 per 45 (Zablotsky, Black, Maenner, Schieve, & Blumberg, 2015). In Canada among children between the ages of 2 and 14, the estimated annual percentage of ASD increased from 9.7 % to 14.8 % in 2010 (Ouellette-Kuntz et al., 2014). In addition the ratio of ASD is approximately 4:1 boys to girls (Huang et al., 2014). It is not clear whether the increase in prevalence of ASD is because of the increase in the disorder, or increase in awareness, right diagnosis, or earlier diagnosis of ASD (Volkmar, Lord, Bailey, Schultz, & Klin, 2004). There are more children being diagnosed with ASD today than before, even though the exact reason for the increase is not known. Given the high prevalence of ASD among children, there is a need for children with ASD to receive interventions that target to reduce the difficulties that they experience.

Motor skills in children with ASD

In addition to the core characteristics of ASD, motor impairments and atypical motor behaviours have been identified in children with ASD since the initial description of Kanner in 1943 (Kanner, 1943). Although studies on motor skills for children with ASD have used different measures, settings, duration, and age ranges, they all suggest that children with ASD often show motor skills that are delayed and of poor quality compared to their peers with typical development (TD) (Bhat, Galloway, & Landa, 2012; Ozonoff et al., 2008; Staples & Reid, 2010; Whyatt & Craig, 2012). Children with ASD have also been found to have abnormal motor movements including repetitive hand flapping, and body rocking (Hattier, Matson, Macmillan, & Williams, 2013; Ming, Brimacombe, & Wagner, 2007), as well as atypical patterns of movements during locomotion, and abnormalities in their posture and gait (Vernazza-Martin et al., 2005). In addition, children with ASD have difficulties with balance, joint flexibility, and speed compared to children with TD (Lang et al., 2010). It has also been suggested that individuals with ASD imitate and complete movements significantly slower than individuals without ASD (Glazebrook, Elliot, & Lyons, 2006). All these motor difficulties may limit the interaction of the child with the physical world during the developmental periods, as a result, can affect the core symptoms of ASD (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010).

Motor delays are present in infants and toddlers at risk for ASD and those later diagnosed with ASD (Bhat, Landa, & Galloway, 2011; Landa & Garrett-Mayer, 2006). For example Teitelbaum, Osnat, Nye, Fryman, and Maurer (1998) investigated the movements of 17 infants later diagnosed with ASD. The authors used the Eshkol-Wachman Movement Analysis System in combination with still-frame videodisc analysis to look at the videos obtained from parents of the infants, long before they were diagnosed with ASD. All the infants showed motor difficulties in all or some of the developmental millstones such as lying, sitting, crawling, and walking (Teitelbaum et al., 1998).

Landa and Garrett-Mayer (2006) conducted a study to examine the development of infants with ASD longitudinally. The researchers recruited 87 infants and divided them into three groups. The first group consisted of 24 infants with ASD, the second one consisted of 11 infants with a language delay, and the third one consisted of 52 infants with TD. In order to determine the level of the infants' development, the authors used the Mullen Scales of Early Learning (MSEL) at the ages of 6, 14, and 24 months old. MSEL assessed five domains of development, including gross and fine motor skills, visual reception, and receptive and expressive language. The results showed no statistically significant differences between the groups at 6 months old, however at 14 months old, in all domains except for visual reception, the ASD group performed significantly worse compared to the children with TD. In addition, at 24 months old, the ASD group was significantly behind in all scales compared to both groups of children with TD and with a language delay, which indicate that as infants and toddlers with ASD grow older, they fall significantly behind their peers in terms of motor skills. This study is important as it provided longitudinal analysis of motor skills of infants at high risk for ASD.

The aim of a study conducted by Provost, Lopez, and Heimerl (2007) was to examine the motor skills in young children ages 21-41 months old with ASD and compare them with motor skills in age-matched children without ASD. The sample consisted of 56 children in three groups: children with ASD (n=19), children with a developmental delay (n=19), and children with developmental concerns without motor delay (n=18). The Bayley Scales of Infant Development-2 as well as the Peabody Developmental Motor Scales-2 were used to assess motor skills of the infants. The results showed that the children with ASD along with the children with a developmental delay had delays in gross motor skills, fine motor skills, or both. The children with ASD also had significant impairments when compared with children who had developmental concerns without motor delay.

In a more recent study Lloyd, MacDonald, and Lord (2013) aimed to describe the gross and fine motor skills of toddlers with ASD by selecting a cross-sectional group of 162 children with ASD (12-36 months old), and a subset of 58 children who were followed longitudinally. For study 1, the authors divided the participants into three age groups (12-24 month old, 25-30 month old, and 31-36 month old). Then, they calculated the toddlers' gross and fine motor difference variable. The variable was used as an indicator of how much the child had motor delay regardless of the chronological age. In study 2, the authors compared the gross motor skills of 58 children with ASD at two different time points, with an average of 12 months apart. The results supported the idea that very young children with ASD have significant motor delays, and significantly fall further behind their chronological age as they get older. The findings from early motor skill investigations show that motor difficulties start at an early age in infants and toddlers with ASD and become more prominent as they age (Landa & Garrett-Mayer, 2006; Lloyd et al., 2013; Provost et al., 2007). Given these results, there is a great need for children with ASD to develop fine and gross motor skills at an early age to prevent any further delay in acquiring motor skills.

Impairments in motor skills start at an early age in infants with ASD and continue throughout childhood (Hawkins, Ryan, Cory, & Donaldson, 2014; MacDonald, Lord, & Ulrich, 2014; Staples & Reid, 2010; Whyatt & Craig, 2012). This was supported by a study conducted by Dido Green et al. (2002). The authors investigated severity of motor impairment of 11 children with Asperger syndrome (six years five months- ten years six month old) and compared them with an age-matched group of nine children with a Specific Developmental Disorder Motor Function. The Movement Assessment Battery for Children (MABC) was used in order to provide the level of motor impairments. The MABC is a standardized assessment for motor performance, and is widely used to identify children who have motor impairments, or are at risk for motor impairments. The assessment consists of three components: a standardized performance test, a teacher checklist, and a set of guidelines for the intervention (Smits-Engelsman, Fiers, Henderson, & Henderson, 2008). The results of the study indicated that all the participants in the Asperger syndrome group had motor impairments. Moreover, in the whole study, five of the six participants with the most severe motor impairments were from the Asperger syndrome group. This study showed the high prevalence of clumsiness and the existence of motor impairments in children with Asperger syndrome, which was formerly considered one of the five Pervasive Developmental Disorders identifying ASDs.

A cohort study conducted by Ming, Brimacombe, and Wagner (2007) investigated the prevalence of motor impairments in children with ASD using the retrospective clinical record review. The authors recruited 154 individuals with ASD between the ages of 2 and 18. The results showed that hypotonia, which is defined as low or reduced muscle tone (Govender & Joubert, 2016), was the most common motor deficit that improved over time. The improvement might be due to interventional therapy, natural progression or both of them. Motor apraxia was also more common among younger children compared to older ones in this study. Motor apraxia is defined as the impairment in executing movements or gestures, despite having the physical ability to perform them (Ming, Brimacombe, & Wagner, 2007). The results also showed that children with fine motor deficits were not more likely to receive interventional services, as compared to the children with ASD without motor deficits. The findings from this study showed that there is a need to conduct interventions for improving gross and fine motor skills in children with ASD.

Children and adults with ASD between the ages of 7 and 32 years old have demonstrated poor limb coordination while performing visuomotor and manual dexterity tasks, and poor lower-limb coordination while performing tasks which require balance, agility, and speed (Bhat et al., 2011). This was supported by a study conducted by Ghaziuddin and Butler (1998), which investigated clumsiness in children with autism, Asperger syndrome, and PDD-NOS. The authors recruited 12 children with Asperger syndrome, 12 children with autistic disorder, and 12 children with PDD-NOS between the ages of 10-12 for this study. The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), which is a standardized test, was used to measure motor coordination. The results showed that all three groups had deficits in motor coordination, with the Asperger group showing the lowest level of impairment in coordination. These findings support the notion that motor skill proficiency is impaired for children with ASD, which can further shows the need to conduct motor skill intervention for this population.

Jansiewicz et al. (2006) used a lager sample size and looked at motor functioning of boys with ASD. The authors recruited a total of 95 boys between the ages of 6 and 17 for the study, with 40 high functioning autism (HFA) and Asperger syndrome participants and 55 with TD. The Physical and Neurologic Examination of Subtle Signs which has a good test-retest reliability (Holden, Tarnowski, & Prinz, 1982), was applied to measure motor skills. The motor tasks in the examination were stressed gait, balance, repetitive time movements, and patterned timed movements. The results showed that both groups of children with HFA and Asperger syndrome had impaired motor function on a wide variety of measures; including greater difficulty with balance and gait, slower speed, more dysrhythmia with timed movements of the hands and feet, and greater overflow while performing timed movements and stressed gait maneuvers. The findings from this study support the existence of motor abnormalities among children with HFA and Asperger syndrome. The study is important since a large sample was used and it further suggests that the motor deficits that children with HFA and Asperger syndrome experience are present in childhood and persist through adolescence.

In a similar study Miyahara et al. (1997) recruited 26 children with Asperger syndrome and 16 children with learning disability between the ages of 6 and 15. The MABC was applied to measure motor function of the participants. The results showed that both groups had a high incidence of motor delays on the MABC total scores. The findings are consistent with the literature and show the need to conduct interventions for children with ASD targeting the motor skills.

A more recent study conducted by Ament et al. (2015) investigated evidence for motor impairment specificity in children with ASD and attention deficit/hyperactivity disorder (ADHD). Two hundred children including 56 with ASD, 63 with ADHD, and 81 with TD between 8 and 13 years old participated in the study. The authors used The Wechsler Intelligence Scale for Children, fourth edition and MABC-2 (Henderson, Sugden, & Barnett, 2007) to examine motor development in the ASD and ADHD groups. The results from this study indicate that the ASD group demonstrated greater overall motor impairment compared to the other groups. In addition to the overall motor deficits, the ASD specifically showed impairments in static balance compared to the other groups. The findings from this study are consistent with the literature, indicating the existence of motor impairments in children with ASD.

Children with ASD face difficulties in social interaction as well as having challenges with social-emotional reciprocity (Rice, Wall, Fogel, & Shic, 2015). There are some studies that aimed to determine if there is a correlation between motor skills and social impairments in children with ASD. Although there is no dominant theory that clarifies why there is a link between them, the researchers think that motor and social skills are interrelated. For example Hilton et al. (2007) conducted a study to investigate if there is any relationship between severity and motor deficits in children with Asperger syndrome. The authors recruited 51 children between the ages of 6 and 12 for the experiment group, and 56 TD children for the control group. They measured the participants' motor skills using MABC. They also measured the social skills using the Social Responsiveness Scale. The results showed a strong correlation between MABC levels and Social Responsiveness Scale severity levels. The findings indicate that there is a link between motor impairments and severity of children with Asperger syndrome.

Adaptive behaviour functioning is necessary for having an independent life and includes performing daily activities, as well as social and communication skills (Gulati & Dubey, 2015). MacDonald et al. (2013) investigated if there is a relationship between motor skills and adaptive behaviour in toddlers between the ages of 14 and 49 months old with ASD. The authors recruited a large sample of 233 children; with 194 of them having ASD, and 39 of them with a developmental delay and no ASD. MSEL was used to measure cognitive development, and The Vineland Adaptive Behaviour Scales, second edition was used to determine adaptive skills. In addition, to access gross and fine motor skills, the researchers used the gross and fine motor scales of the MSEL. The results showed that both gross and fine motor skills of the participants were correlated with their adaptive behaviour, meaning that children with higher scores for motor skills, scored better in adaptive behaviour skills as well. These findings demonstrate the importance of early motor development interventions for the development of motor skills, adaptive behaviour, and overall functioning for children with ASD.

In a similar study Kokubun (2014) aimed to determine if there is a relationship between motor and social skills in children with ASD. Twenty six children between the ages of 7 and 16 were recruited to take part in this study. The authors applied MABC-2 to assess motor skills, and Social Responsiveness Scale to assess social skills. MABC-2 is a revision of MABC and is used widely as an assessment tool by occupational therapists, physiotherapist, psychologists, and educational professionals. MABC-2 identifies and describes impairments in motor performance of children between the ages of 3 and 17 years old and has two parts. For the first part, children are asked to complete different fine and gross motor tasks, which are separated into three categories: Manual Dexterity, Aiming and Catching, and Balance. The second part consists of a checklist completed by an adult, which rates child's motor competence on a 30-item scale (Brown & Lalor, 2009). In this study, the children had the most difficulty with manual dexterity. The authors also found that individual differences in social impairment were strongly interrelated with problems with manual dexterity, which is consistent with the literature indicating a correlation between motor and social skills in children with ASD.

Overall, the literature clearly indicates that children with ASD usually have poor motor skills which start from infancy and continue throughout the childhood, and can become worse as they get older (Green et al., 2002; Lloyd, MacDonald, & Lord, 2013;

Miyahara et al., 1997; Staples & Reid, 2010; Whyatt & Craig, 2012). During childhood, motor skills can provide a means for learning important skills in other domains such as social, leisure, and academic, which can further develop motor and social skills (Baranek, 2002). As a result, the impairment in motor abilities can lead to reduced opportunities to engage in play, school, recreational and physical activity (Block, Block, & Halliday, 2006), thus the children may not receive potential physical, psychological, and behavioural benefits of such activities. As a result, there is a need to conduct motor skill interventions which aim to improve motor skills of children with ASD.

Motor Skill Interventions for Children with ASD

Children with ASD often experience difficulties in motor skills (Liu & Breslin, 2013; Lloyd et al., 2013; Ozonoff et al., 2008; Staples & Reid, 2010; Whyatt & Craig, 2012). Motor skills are essential for the children’s ability to engage in play, recreational, and daily living activities. Participating in recreational and physical activities is important for children with ASD, as these activities have been reported to have various benefits for the children. These benefits include providing an opportunity to develop motor skills, physical fitness, and social interaction, as well as to develop a healthy lifestyle (Pan, 2010; Todd & Reid, 2006). Therefore, motor difficulties along with poor social skills can result in insufficient opportunities to participate in recreational programs as well as a lower level of physical activity. Subsequently, this causes developmental consequences for children with ASD who do not develop motor skills and do not learn how to engage in physical activities (Bhat et al., 2011; Lee & Porretta, 2013). Thus, it is important to conduct motor skill interventions that aim to improve motor skills in children with ASD.

There are few studies in the literature that looked at the effect of motor skill interventions on motor skills of children with ASD. For example, Bremer, Balogh, and Lloyd (2015) investigated the effect of a fundamental motor skill intervention on motor skills, adaptive behaviour, and social skills of 4 year old children with ASD. The authors recruited 9 children to participate in the study (Five participants in group one, and four participants in group two). Group one received the intervention one hour per week for 12 weeks, and group two received the intervention two hours per week for six weeks. The results showed significant improvements in motor skills following the intervention. Adaptive behaviour and social skills also improved after the intervention. The findings from this study suggest that fundamental motor skill interventions can be effective at improving the motor skills in children with ASD.

Yilmaz, Yanardağ, Birkan, and Bumin (2004) investigated the effectiveness of a 10 week swimming intervention on motor performance and physical fitness of a 9 year old boy with ASD. The intervention was performed three times a week for 60 minutes each session. The assessments were performed before and after the intervention, and included: six minute walking test to determine the peak VO2, standing on one leg (both right and left foot) to assess static balance, thrust test to measure agility, standing board jump test to assess power, the hand dynamometer to determine grip strength, shoulder flexion and knee extension to measure strength, a 22.86 m running test to assess speed, and sit and reach test, as well as lateral flexion test to assess flexibility. The results of this study indicated that the 10 week swimming program improved the child's balance, speed, agility, hand grip, strength, cardiorespiratory endurance, flexibility, and power increased following the intervention (Yilmaz et al., 2004).

Similarly Huettig and Darden-Melton (2004) examined the effectiveness of a four year long swimming intervention on aquatic skills of four children between the ages of 7-13 with ASD. The aquatic skills were examined before, during, and after the intervention. The results showed improvements in aquatic skills including water orientation, breathing, floating, stroke, and entry and exit skills for all the participants.

In a similar study Pan (2010) looked at the effect of a water exercise swimming program on the aquatic and social skills of children with ASD. Sixteen boys ages 6-9 with ASD participated in the study. During the first 10 week, eight participants received the intervention, whereas the other eight participants did not. The second 10 weeks started immediately after the first one, with the treatment reversed. Improvements in aquatic skills were seen in both groups following the intervention. After the first 10 weeks, significant improvements in social skills were seen for the first group. Following the second 10 weeks, social skills improved for the second group, however, the first group only maintained the improvements. The swimming interventions provided useful information on the effective duration and dosage of a motor skill intervention for children with ASD, however, due to the limited number of participants in the studies, it would be difficult to expand the results for all children with ASD.

A systematic review conducted by Lang et al. (2010) identified 18 studies investigating the effectiveness of physical exercises on children with ASD. The selected studies looked at the age group of 3 to 41 years old and consisted of a variety of exercise activities such as jogging, weight training, and bike riding. After performing the interventions, there was a decrease in stereotyped behaviour, aggression, and off-task behaviour. There was also an increase in on-task behaviour, academic responding, and appropriate motor behaviour following the interventions. The findings show that physical exercise can be beneficial for children with ASD and if it becomes a preferable activity for the children, it can encourage more participation in physical exercises. However, the interventions included in this systematic review were not sport specific motor skill interventions, and the exercise applied was mainly jogging. More research is needed on investigating the effectiveness of actual motor skill interventions on children with ASD.

Wuang, Wang, Huang, and Su (2010) conducted a study to determine the effectiveness of a simulated developmental horse-riding program (SDHRP) on children with ASD. Sixty children with ASD (6-8 years old) participated in the study. The intervention consisted of two phases. For the first phase, 30 children received SDHRP besides their regular occupational therapy for 20 weeks, whereas the other group only received regular occupational therapy. For the second phase of the study which was also 20 weeks long, the arrangement was reversed. The intervention was performed twice a week, for 60 minutes per session. The authors used Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) to assess the participants' gross and fine motor skills. The results showed that the children with ASD improved their motor proficiency after receiving the intervention. As a result, SDHRP can be effective at improving motor skills in children with ASD.

Although many studies have shown that children with ASD have motor deficits (Jasmin et al., 2009; Liu & Breslin, 2013; Staples & Reid, 2010; Whyatt & Craig, 2012), motor impairments do not take place in the ASD diagnosis criteria; and most of the studies for children with ASD solely focus on improvements in the three core characteristics of ASD. Although positive effects of improvements in motor skills for children with ASD have been reported in the literature, motor skill interventions for children with ASD have been a neglected area (Baranek, 2002). There is limited research focusing on the effectiveness of motor skill interventions on children with ASD (Bremer et al., 2015). There is a need to conduct motor skill interventions for children ASD targeting to improve motor skills in this population.

Balance in Children with ASD

Postural control is a determinant of balance (Huxham, Goldie, & Patla, 2001), a necessary component among children for all physical activities of normal functioning (Condon & Cremin, 2014). Since balance is a fundamental requirement for motor development in children (Fabbri-Destro, Gizzonio, & Avanzini, 2013), dysfunction in balance can result in limitations in performing motor skills (Dewar, Love, & Johnston, 2015; Silkwood-Sherer, Killian, Long, & Martin, 2012). In addition, the difficulties with balance can result in problems with activities of daily living (Edgren et al., 2013; Huxham et al., 2001), as well as limiting the children’s participation in various activities such as leisure and play, thus, exacerbating core symptoms of ASD by limiting social interactions (Travers, Powell, Klinger, & Klinger, 2013).

Although researchers have used a variety of methodologies for evaluating postural control and balance in children with ASD, they have all shown that children with ASD experience difficulties with postural control and balance (Chang, Wade, Stoffregen, Hsu, & Pan, 2010; Memari, Ghanouni, Shayestehfar, & Ghaheri, 2014; Travers et al., 2013)

(Despina Arzoglou et al., 2013; Chang et al., 2010). The impairments in postural control and balance can start appearing from early years and continue throughout childhood in children with ASD (Travers, Powell, Klinger, & Klinger, 2013; Baranek, 1999; Memari et al., 2014). Moreover, the deficits in balance and motor coordination can be seen across the whole spectrum. For example, even children with HFA have been found to have difficulties with performing motor tasks that require motor coordination (Jones & Prior, 1985), which shows the need for improving balance and motor coordination in children with ASD.

In a systematic review, Fournier, Hass, Naik, Lodha, and Cauraugh (2010) examined motor coordination of children with ASD and compare it with motor coordination in children with TD. The results showed that individuals with ASD had lower coordination compared to their peers with TD. In a similar review of evidence, Dawson and Watling (2000) reported that individuals with ASD have impairments in eye-hand coordination, gait, posture, and balance. Since balance is necessary to develop motor skills, interact with the environment, and perform daily living activties (Silkwood-Sherer et al., 2012), it is essential to condcut interventions to improve balance in children with ASD.

Rinehart et al. (2006) aimed to investigate gait functioning in children with HFA and Asperger syndrome. The participants of the study consisted of ten children with HFA, 10 children with Asperger syndrome, and 10 children with TD. The researchers evaluated the gait in the participants under three conditions: preferred, cued, and noncued gait. The results showed that the Asperger syndrome group did not have any gait deficits, however, the HFA group demonstrated gait deficits compared to the TD group, which further support gait abnormalities in children with HFA. Since normal gait is critical to an individual's quality of life (Gui & Liu, 2011), it is important to improve gait in children with ASD.

Children with ASD have impaired or immature postural control even under the most basic conditions such as quiet stance and gait initiation (Fournier, Kimberg, et al., 2010). Fournier, Kimberg, et al. (2010) aimed to evaluate static and dynamic balance in children with ASD by examining postural sway during quiet stance, as well as examining the centre of pressure shift mechanism during gait initiation. This study included 13 individuals ages 8-14 years old with ASD and 12 age-matched individuals with TD. The results indicated that children with ASD demonstrated poor static and dynamic balance compared to their peers. Therefore, the findings supported the existence of impairments in balance among children with ASD.

A study conducted by Kohen-Raz, Volkman, and Cohen (1992) aimed to compare static balance and postural control between individuals with ASD, intellectual disability, and TD. The authors recruited 91 individuals with ASD, 18 children with an intellectual disability, and 166 individuals with TD between the ages of 4 to 20. To assess postural control, each subject stood on four footplates and assumed different standard postures including the four Romberg positions (standing with feet parallel, first with eyes open, and then with eyes closed, with and without placement of the subject on elastic pads). Participants had to maintain each posture for 20 seconds. The results showed that children with ASD had higher postural instability compared to the other two groups of this study (Kohen-Raz, Volkman, and Cohen, 1992), which is in line with the literature showing impaired postural stability and balance for children with ASD.

In a similar study, Molloy, Dietrich, and Bhattacharya (2003) aimed to evaluate the postural stability and static balance in children with ASD and compare it with postural stability in children with TD. The authors recruited eight boys with ASD and eight age- and race-matched boys with TD. In order to assess postural stability, the testing was completed in four different conditions: (1) eyes open, feet on platform; (2) eyes closed, feet on platform; (3) eyes open, feet on foam; (4) eyes closed, feet on foam. The participants were asked to maintain their balance for 30 seconds under each condition. The findings of the study showed that children with ASD had significantly larger sway compared to their peers with TD (Molloy, Dietrich, & Bhattacharya, 2003). The results from this study are consistent with other studies, indicating that children with ASD have poor postural control and static balance.

Minshew, Sung, Jones, and Furman (2004) aimed to investigate whether there is any abnormality in postural control in individuals with ASD and whether the abnormality is age related. The authors recruited 79 individuals with HFA without an intellectual disability, and 61 individuals with TD between the ages of 5 and 52 and examined their postural stability and movement coordination. Each subject stood on either a fixed platform or a sway-referenced platform. The position of the centre of force was recorded during 15 second trials. There were six conditions for the test: (1) fixed platform, eyes open with fixed visual surround; (2) fixed platform, eyes closed; (3) fixed platform eyes open with sway-referenced visual surround; (4) sway-referenced platform, eyes open with fixed visual surrounds; (5) sway-referenced platform, eyes closed; (6) sway-referenced platform, eyes open with sway-referenced visual surround. The results from this study indicate that individuals with ASD had poor postural stability, as well as a delay in the development of postural control compared to their peers with TD. The findings support the notion that it is important to design interventions for children with ASD aiming to improve balance in this population.

The purpose of the study conducted by Travers et al. (2013) was to link symptom severity and static balance and postural stability in adolescents and adults with ASD. The authors recruited 26 individuals between the ages of 16 and 28 with ASD, and 26 participants between 18 to 30 years old with TD. The researchers used a Nintendo Wii balance board to measure postural stability. The participants were asked to stand on the balance board with both feet and complete six tasks for 45 seconds each or until they lost balance. The tasks included: (1) standing on two feet with eyes open; (2) standing on two feet with eyes closed; (3) standing on right foot with eyes open; (4) standing on left foot with eyes open; (5) standing on right foot with eyes closed, and (6) standing on left foot with eyes closed. The results suggested that individuals with ASD had significantly lower postural stability compared to the other group of the study. Moreover, it was indicated that postural stability and static balance during two-legged standing was related to autism symptom severity.

The literature shows that children with ASD have impairments in postural control and balance (Arzoglou et al., 2013; Kohen-Raz, Volkman, & Cohen, 1992; Memari et al., 2014; Molloy et al., 2003), which can affect the development of motor skills, thus limiting the participation opportunities in leisure, physical, and school activities. As a result, it is essential to implement interventions targeting postural control and balance in children with ASD.

Gymnastics and Motor Skills

Gymnastics is a sport which provides a base for motor skill acquisition (Gymnastics Canada Gymnastique, 2008), and can improve essential elements necessary for motor development such as balance and coordination (Ana-Maria, 2014; Torlakovic, Muftic, Avdic, & Kebata, 2013; Vuillerme et al., 2001). In addition, engagement in gymnastics training provides a number of positive benefits for children's motor development such as developing flexibility, strength, and speed (Donham-Foutch, 2007; Gymnastics Canada Gymnastique, 2008; Kirby, Simms, Symington, & Garner, 1981; Zetaruk, 2000). In recreational gymnastics, participants perform basic movement patterns such as walking, running, balancing, jumping, and landing. Since there is no need to have high levels of training for recreational gymnastics, it can be taught to children with different levels of ability (Kurnik et al., 2013). In Canada, among the 200,000 registered gymnasts, only a small percentage participate in competitive gymnastics, whereas over 90% of this population participate in recreational classes and learn basic motor skills through gymnastics activities (Gymnastics Canada Gymnastique, 2008).

Balance is a required element to perform motor skills (Vuillerme et al., 2001) which can be positively affected through gymnastics training. For instance, Carrick et al. (2007) conducted a study to examine if balance and stability in gymnasts are different from non-gymnasts. One hundred sixty six gymnasts and 236 non-gymnasts (10-37 years old) were recruited to participate in this study. The authors used computer dynamic posturography which is a standard diagnostic test of balance function, and calculated the relationship between the postural control in two groups. The results demonstrated that gymnasts have more stable posture compared to non-gymnasts, which can show that gymnastics can improve balance in individuals.

There is more evidence supporting the potential benefits of gymnastics at improving balance. For example, Aydin, Yildiz, Yildiz, Atesalp, and Kalyon (2002) conducted a study to determine if gymnastics has any effect on balance and proprioception of the ankle. The authors recruited 40 female adolescent gymnasts and non-gymnasts and assigned them into groups of 20. One group consisted of gymnasts and the other consisted of non-gymnasts. Four different tests were applied in order to assess the sense of proprioception ability of the ankle. The tests included: (1) one leg standing test; (2) single-limb hopping test; (3) active angle-reproduction test; (4) passive angle-reproduction test. The authors used a dynamometer to actively measure the sense of position of the joint, and a proprioception- testing device to passively measure it. The results showed that gymnasts had a better sense of position of the ankle joint and balance, thus indicating that gymnastics can promote balance.

Marina and Torrado (2013) evaluated the effect of different types of training on muscle strength and anaerobic power in children from different sports and different levels of performance. The authors recruited 184 children ages 11-12 who were participating in swimming, tennis, handball or gymnastics. Anaerobic performance, squat jumps, and drop jump was evaluated. The results showed that the gymnasts had the most explosive muscular performance in higher squat jumps and counter movement jumps, and better drop jumps than the other athletes. The findings show that gymnastics can improve muscle strength and anaerobic power in children, thus can be a beneficial activity for children.

Overall, gymnastics can develop the foundation for various motor skills in children by offering different body movements such as rolling, jumping, hopping, and running (Gymnastics Canada Gymnastique, 2008). In addition, gymnastics can improve body awareness and neuromuscular coordination in children (Gruodyte-Raciene et al., 2013), thus affecting the children's overall development. Moreover, improving motor skills in children can encourage more participation in recreational activities. Therefore, gymnastics can be a beneficial activity for children with ASD.

Effect of Gymnastics on Motor Skills in Individuals with Disabilities

Even the recreational level of gymnastics involves the development of muscular strength, balance, spatial and body awareness, as well as neuromuscular coordination (Gruodyte-Raciene et al., 2013; Fotiadou et al., 2009). Fotiadou et al. (2009) aimed to investigate the effectiveness of a gymnastics intervention on the dynamic balance in individuals with intellectual disability. The authors recruited 18 adults ages 23-35 with intellectual disability. Ten participants formed the intervention group, and eight formed the control group. The intervention group received 12 weeks of gymnastics training three times a week, where each session lasted 45 minutes. The authors measured the dynamic balance before and after the intervention using a balance deck. They recorded the number of seconds the participants could remain standing on the platform of the stabilometer in durations of 30, 45, and 60 seconds. The authors reported that the intervention group demonstrated a significant improvement in dynamic balance after applying the program. Therefore, the article can conclude that gymnastics can have potential benefits for improving dynamic balance in individuals with intellectual disability.

Moraru, Hodorca, and Vasilescu (2014) conducted a study to determine the effectiveness of gymnastics and dance rehabilitation in three children with Down syndrome. The participants were between the ages of 10-14 and received the intervention for eight months. The authors applied FUNfitness testing protocol to measure joint flexibility, muscle elasticity, force, and balance of the participants. It was noted that after the intervention, there was an increase in single-leg stance stability, a decrease in execution time of sitting lifting test, and an improvement in abdominal muscle strength by increasing the number of repetitions. The findings from this study suggest that gymnastics and dance may have a positive effect on motor skills in children with Down syndrome, thus show the importance of implementing gymnastics and dance in the daily schedule of these children.

Effect of Gymnastics on Motor Skills in Individuals with ASD

There is no research in the literature investigating the effectiveness of a gymnastics intervention on motor skills and balance of individuals with ASD. There is only one letter to the editor regarding to an article about the method of stimulated serial repetitions of gymnastics exercise in therapy of children with ASD (Szot et al., 1997). In the letter, it was mentioned that the participant received a series of exercises with a minimum of five repetitions in one set. As the skill improved, the number of exercises increased. With a four-year observation, it was shown that there was a relationship between the repetition and changes in exercises, as well as changes in the participant's behaviour. Therefore, there is a gap in the literature in terms of the effect of gymnastics on motor skills of children with ASD.

Summary

Children with ASD experience difficulties in communication and social skills, and demonstrate restricted patterns of behavior, interests, and activities (American Psychiatric Association, 2013). Moreover, children with ASD usually have motor skills that are delayed and have poor quality, as well as impaired balance (Liu & Breslin, 2013; Lloyd, MacDonald, & Lord, 2013; Ozonoff et al., 2008; Provost, Lopez, & Heimerl, 2007; Staples & Reid, 2010; Whyatt & Craig, 2012). Poor motor skills and balance can inhibit the children from engaging in recreational and daily activities, as well as playing with their peers. Consequently, this lack of engagement can cause further difficulties with the development of motor, social, and communication skills (Gallo-Lopez & Rubin, 2012; Gibson, 2000). Gymnastics can have a positive effect on motor skills and balance of children (Carrick, Oggero, Pagnacco, Brock, & Arikan, 2007; Donham-Foutch, 2007; Fotiadou et al., 2002; Zetaruk, 2000); however, no published study has looked at the effectiveness of a gymnastics intervention on motor skills and balance of children with ASD. This study will fill the gap in the literature by conducting a gymnastics intervention and examining its impact on motor skills and balance of children ages five to nine with ASD.

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Chapter 3: Manuscript:

Investigating the effectiveness of a gymnastics intervention on motor skills and balance of children between the ages of five to nine with Autism Spectrum Disorder

Introduction

Motor Skills in Children with ASD

Children with Autism Spectrum Disorder (ASD) experience deficits in social commutations and social interactions, and demonstrate restricted patterns a of behaviour, interests, or activities (American Psychiatric Association, 2013). Studies have shown that the prevalence of ASD has increased over time (Baio, 2014; Kogan et al., 2009); the current estimated prevalence of ASD is 1 per 45 (Zablotsky, Black, Maenner, Schieve, & Blumberg, 2015). The ratio is significantly higher in males compared to females, with approximately four males having ASD for every female (Carter et al., 2007).

Aside from the core characteristics, impairments in motor skills are commonly observed in children with ASD and infants at risk of ASD (Bhat, Landa, & Galloway, 2011; Chang, Wade, Stoffregen, Hsu, & Pan, 2010; Fournier et al., 2010; MacDonald, Lord, & Ulrich, 2013; MacDonald, Lord, & Ulrich, 2014; MacNeil & Mostofsky, 2012; Osterling, Dawson, & Munson, 2002; Ozonoff et al., 2008; Staples & Reid, 2010; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). Nickel, Thatcher, Keller, Wozniak, and Iverson (2013) suggested that infants at high familial risk for ASD have delayed posture development and postural instability. There is also evidence that young children with ASD display atypical and repetitive patterns of movements such as arm waving or abnormal body position when crawling (Rinehart, Bradshaw, Brereton, & Tonge, 2001; Sacrey, Bennett, & Zwaigenbaum, 2015; Zwaigenbaum, Bryson, & Garon, 2013). It is difficult to tell whether these observable patterns are part of restricted and repetitive behaviours that children with ASD often exhibit, or rather due to an underlying impairment in motor skills. Regardless of the reason, the early motor differences that can emerge before the appearance of social-communication differences in infants later diagnosed with ASD, can be among the earliest observable signs and indicators of ASD (Landa & Garrett-Mayer, 2006; Zwaigenbaum et al., 2013). The early detection of these signs is important because it can allow for earlier motor, and behavioural interventions.

Motor impairments are not only seen at an early age in children with ASD, but also can be observed throughout the childhood and adulthood (Ament et al., 2015; Bhat et al., 2011; Chang et al., 2010; Fournier et al., 2010; Ming, Brimacombe, & Wagner, 2007). Research has indicated that as these children get older, the impairments sometimes worsen (Landa & Garrett-Mayer, 2006; Lloyd, MacDonald, & Lord, 2011), which can result in difficulties in leisure and daily living activities (Edgren et al., 2013; Huxham et al., 2001). The existence of these difficulties demonstrates the need to conduct interventions targeting motor skills of children with ASD.

As children get older, they use motor skills to interact with others, play with their peers, participate in active play, and perform other daily activities (Twarek, Cihon, & Eshleman, 2010). Participating in active play can be a critical element for overall child development (Alexander, Frohlich, & Fusco, 2014). It is important to provide the necessary opportunities for children to help them acquire the motor skills needed for active play. Although impairments in motor skills are not listed among the diagnostic criteria of ASD and have not received as much attention in research studies (American Psychiatric Association, 2013), they can contribute to the functional difficulties for children with ASD (Fabbri-Destro, Gizzonio, & Avanzini, 2013; Hilton et al., 2007), and may result in insufficient opportunities to participate in leisure activities (Lee & Porretta, 2013). This can interfere with the development, social relationships, and even mental and physical health of the child with ASD (Law et al., 2006).

Research indicates that children with ASD also have poor fine motor skills (Provost, Lopez, & Heimerl, 2007), which can be among the early predictors of later delays for children with ASD (LeBarton & Iverson, 2013). Landa and Garrett-Mayer (2006) found fine motor delays in 14 month old infants at higher risk for ASD who were later diagnosed with ASD. These delays exist through 24 months (the oldest age reported in that study). In addition, Libertus, Sheperd, Ross, and Landa (2014) suggest that there are differences in fine motor skills between infants at a lower risk for ASD and those at a higher risk. These differences especially exist on grasping and object exploration-related skills. Oral-motor skills are also associated with manual-motor (hand and finger) skills (Corbetta & Thelen, 1996), therefore delays in fine motor skills often co-occur with the expressive language delays (Stone & Yoder, 2001). In a different study Gernsbacher, Sauer, Geye, Schweigert, and Hill Goldsmith (2008) found that fine motor skills in the first two years of children with ASD can predict their later speech fluency

Difficulties in fine motor skills have been shown to persist into childhood. For example, Fournier, Hass, Naik, Lodha, and Cauraugh (2010) conducted a meta-analysis that included research on individuals with ASD at different ages. The results showed that individuals with ASD had difficulty with fine motor skills, which start in infancy and continue into childhood. As a result identifying fine motor skill difficulties in children with ASD can help researchers and therapist provide important information about areas of strength and areas in which these children would need assistance with during the childhood years. Therefore, it is important to conduct intervention for children with ASD aiming to improve fine motor skills in this population. Children with ASD can improve their fine motor skills through fine motor skill interventions (Aparicio & Balaña, 2009; Ohl et al., 2013).

Balance in Children with ASD

Children with ASD have also been reported to have poor balance and postural control (Arzoglou et al., 2013; Memari, Ghanouni, Shayestehfar, & Ghaheri, 2014; Minshew, Sung, Jones, & Furman, 2004). Balance is defined as the ability to maintain equilibrium while the centre of gravity is stationary (static balance) or as it shifts (dynamic balance) (Jazi, Purrajabi, Movahedi, & Jalali, 2012). Balance is an essential component in the motor development of children and can help them maintain a desired physical position (Chang et al., 2010; Fabbri-Destro et al., 2013). Poor balance can lead to injuries resulting from falling (Granacher, Muehlbauer, Maestrini, Zahner, & Gollhofer, 2011; McCoy et al., 2015), but most importantly, it can contribute to difficulties with learning new skills and loss of independence in children, which can affect their function and participation at home, school, and in the playground. This lack of participation can lead to exclusion of the children from social activities (Silkwood-Sherer, Killian, Long, & Martin, 2012). Given the importance of balance for children, it is crucial to develop interventions for children with ASD that aim to improve their static and dynamic balance.

The results of existing literature consistently identify a lack of balance, postural stability, motor coordination, and gait abnormalities in children with ASD (Arzoglou et al., 2013; Minshew et al., 2004; Molloy, Dietrich, & Bhattacharya, 2003; Rinehart et al., 2006).

Molloy et al. (2003) reported that children with ASD had significantly larger sway areas compared to children with typical development (TD), which can be an evidence of an impaired control of posture in children with ASD. Memari et al. (2014) conducted a critical review to summarize the literature on postural control in children with ASD. The researchers looked at the studies between 1992 and 2013 and 14 studies met the inclusion criteria. The results suggested that children with ASD have problems maintaining postural control as early as infancy, which persists into later years. It has also been reported that children with ASD demonstrate less stable postural control compared to children with TD and children with intellectual disability (Kohen-Raz, Volkman, & Cohen, 1992). Poor postural control can cause difficulty in performing or learning new motor skills, and in everyday tasks that require higher level of balance and coordination.

Motor Skill Interventions for Children with ASD

With more children being diagnosed with ASD now than in the past, along with the importance of motor skills and balance, there is a need to conduct motor skill interventions for children with ASD. The limited number of studies looking at the effect of motor skill interventions for children with ASD have indicated that children with ASD can improve their motor skills through motor skill interventions (Bremer, Balogh, & Lloyd, 2015; Bremer & Lloyd, 2016; Lang et al., 2010; Wuang, Wang, Huang, & Su, 2010). Bremer et al. (2015), for example, investigated the effect of a fundamental motor skill intervention on the motor skills of four year-old children with ASD. Skills taught to the participants included both locomotor and object control skills, which progressed in terms of difficulty during the intervention. The MABC-2 was used at baseline and Peabody Developmental Motor Scales-2 was used at every assessment period to measure children’s motor skills.

Following the intervention, in comparison to the control group, the intervention group demonstrated significantly higher object control skills and overall motor scores. The results from this study suggested that by implementing motor skill interventions for children with ASD, motor skills of the children can improve. Yilmaz, Yanarda, Birkan, and Bumin (2004) also conducted a case study looking at the effect of a swimming intervention on a 9 year old child with ASD. The intervention included 10 weeks of swimming training, and the results showed improvement in balance, agility, speed, strength, and hand grip. The findings suggested that a swimming intervention can positively impact motor skills of children with ASD. In a more recent study Bremer and Lloyd (2016) examined the effectiveness of a fundamental motor skill intervention on motor skills of five children ages three to seven years old with autism-like characteristics. The intervention was conducted for two 6-week blocks. Motor skills were evaluated prior to the beginning of the intervention. Similar to the previous studies, the results showed that there was an improvement in fundamental motor skills of the participants following the intervention. Results from these studies suggested that motor skill interventions can be effective for children with ASD and can improve the overall motor skills. However, more variety in the type of interventions is needed.

Gymnastics and Motor Skills

Gymnastics is a common activity for young children and can develop the foundation for motor skills including strength, flexibility, balance, and coordination, as well as spatial awareness (Donham-Foutch, 2007). Gymnastics offers various locomotor, stability, and body control movements and can be the used for the development of physical literacy (Gymnastics Canada Gymnastique, 2008). Moreover, motor skills such as jumping, rolling, and landing are core features of gymnastics (Coelho, 2010) which can all contribute to the acquisition of motor skills for the participants. Gymnastics activities can also help children develop spatial and body awareness, muscle strength, and neuromuscular coordination (Gruodyte-Raciene, Erlandson, Jackowski, & Baxter-Jones, 2013), all important for an overall healthy development. There are two types of gymnastics (competitive and recreational). In contrast with competitive gymnastics, participants do not require to have high levels of training in recreational gymnastics, therefore it is possible to easily teach it to children (Kurnik, Kajtna, Bedenik, & Kovač, 2013). Recreational gymnastics exercises can also be modified in order to meet the needs of children with any ability, thus, it is hypothesized that gymnastics could be a suitable modality to teach to children with ASD to enhance motor skills.

Only a limited number of studies have been conducted to investigate the effect of gymnastics on individuals with disabilities, and none of them include young children in their samples. (Fotiadou et al., 2009; Moraru, Hodorca, & Vasilescu, 2014). All of the identified studies suggest that gymnastics interventions can be effective at improving motor skills of individuals with disabilities (Fotiadou et al., 2009; Moraru et al., 2014). One of these studies conducted by Moraru et al. (2014) examined the effectiveness of a gymnastics and dance rehabilitation on motor capacities of three children aged 10-14 years with Down syndrome. The results indicated an improvement in one leg stance stability, abdominal muscle strength, and a decrease in execution time sitting lifting test (Moraru et al., 2014). It is not clear whether the improvements resulted from the gymnastics or dance, or a combination of both. Another study conducted by Fotiadou et al. (2009) aimed to determine the effect of rhythmic gymnastics on dynamic balance of 18 individuals ages 23-25 years with intellectual disability. The intervention group underwent 12 weeks of rhythmic gymnastics intervention, whereas the control group did not. Results showed that the intervention group significantly improved their dynamic balance after receiving the intervention. The studies by Fotiadou et al. (2009) and Moraru et al. (2014) indicate that participation in gymnastics can help individuals with developmental disabilities to develop better balance, thus improving their overall motor skills. However, more research using larger samples, younger children, and other participants with developmental disabilities is needed (Fotiadou et al., 2009; Moraru et al., 2014) No studies have investigated the use of gymnastics on children with ASD, and there is only one letter to the editor referring to an article about the method of stimulated serial repetitions of gymnastics exercise in therapy of children with ASD (Szot et al., 1997). In the letter it was mentioned that the participant received a series of exercises with a minimum of five repetitions in one series. As the skill improved, the number of exercises increased. With a four-year observation, it was demonstrated that there was a relationship between the repetition and changes in exercises, as well as changes in the participant's behaviour. Therefore, there is a gap in the literature in terms of the effect of gymnastics on motor skills of children with ASD, and a need for conducting research looking at the effect of gymnastics on motor skills of individuals with ASD.

Gymnastics Long-Term Athlete Development Model

The Long-Term Athlete Development (LTAD) model is a pathway guiding individuals in sports and physical activity from infancy to adulthood. All Canadian sport organizations have their own specific LTAD model, including Gymnastics Canada (Balyi, Way, & Higgs, 2013). The LTAD model consists of eight stages, along with two additional stages for individuals with a disability, the awareness stage and the first involvement stage. The first stage of LTAD is called Active Start which is designed for children zero to six years of age. This stage along with stages two and three help children develop basic motor skills and fundamental movement skills needed for an active life (Balyi et al., 2013). During Active Start children work towards developing motor qualities such as balance, coordination, and agility, and are introduced to the fundamental movement skills (Gymnastics Canada Gymnastique, 2008). The movements used during this stage include various types of jumping, rolling, kicking, running, and twisting. Moreover, social skills, communication, and body awareness are among the areas that can be developed through participating in gymnastics programs at the Active Start stage. Since fundamental movement skills are the foundation for participation in many sports and physical activities, if a child is not given the opportunity to develop fundamental movement skills, they are more likely to experience difficulties participating in sport activities in the future (Gymnastics Canada Gymnastique, 2008). According to the gymnastics LTAD model, individuals with a disability can be integrated into gymnastics programs, specifically if a support person, parent/guardian can participate in the program with the individual. According to LTAD model, children four to six years of age should receive 45-60 minutes of gymnastics lessons once or twice per week (Gymnastics Canada Gymnastique, 2008).

In Stage two, known as Fun, Fitness, and Fundamental Movement Patterns stage, participants continue developing fundamental movement skills in a multi-gymnastics environment (Gymnastics Canada Gymnastique, 2008). At this stage, children start learning gymnastics specific sport skills, which can be beneficial for both competitive and recreational sports, and will further improve the quality of life and health of the participants. Many participants will move to other sports after this stage. Those participants who are interested in more advanced gymnastics, will be streamed into programs that suit their ability. At this stage fundamental movement patterns are performed at a more advanced quality compared to the Active Start stage. In addition, self-confidence, self-expression, and group social skills are taught to the participants. The suggested amount of time for this stage is one to an hour and a half per week. Participants in this study were at the Active Start and Fun, Fitness, and Fundamental Movement Patterns stages. Therefore the activities chosen for the program were based on the stage one and two of LTAD model for Gymnastics Canada (Balyi et al., 2013).

The primary purpose of this study was to investigate the effectiveness of a gymnastics intervention for children between the ages of five to nine with ASD, compared to a fine motor intervention. The secondary purpose was to investigate whether there is any effect on static and dynamic balance for children ages five to nine with ASD after receiving a gymnastics intervention. Currently there is no research investigating the effect of gymnastics interventions on motor skills, static, and dynamic balance of children with ASD. It was hypothesized that by participating in gymnastics intervention, there would be improvements in motor skills and balance of children with ASD, and by participating in a fine motor intervention as the control group, there would be improvements in fine motor skills of the participants.

Methods

Study Design

Ethical approval was received from the University of Ontario Institute of Technology Ethics Board (Appendix 1) and Grandview Children's Centre Research

Committee which is a local children's treatment centre. All of the parents provided informed consent prior to the beginning of the study (Appendix 2) and the participants involved in the study provided child assent (Appendix 3). The study employed a pre-test/post-test design with a 4-week follow up. Participants attended three assessments: A pre-assessment prior to the beginning of the interventions, a post-assessment one week following the interventions, and a 4-week follow up assessment. The motor skills, static and dynamic balance were measured during these assessments. Twelve children with ASD enrolled in this study; however two of the participants did not attend the post-test and follow-up, therefore, their data has been excluded, leaving 10 participants; five participants in the gymnastics group, and five participants in the fine motor group. At the end of the pre-assessment, each child was randomly assigned into a gymnastics or fine motor group. Each participant received the same amount of intervention regardless of the group to which they were assigned.

Recruitment

Children ages fine to nine with ASD were recruited through a social media post advertising the gymnastics and fine motor interventions on Grandview Children's Centre social media page (Appendix 4), and two local gymnastics clubs (Appendix 5). Eligibility for the study was established using five screening questions. The questions included: (1) Whether the child had an Autism Spectrum Disorder diagnosis? (2) Whether the child was between five-nine years of age? (3) Whether the child was able to follow two-step instructions? (4) Whether the child could see, hear, and walk independently? and (5) Whether the child exhibits aggressive behaviour towards others or him/herself? If the answers were yes to questions 1, 2, 3, and 4, and no to 5, the child was eligible to participate in the study. The gymnastics group consisted of five participants (three male, two female), and the fine motor group consisted of five participants (four male, one female)

Procedure

All measurements were conducted at the UOIT Motor Behaviour and Physical Activity Lab with the children and their parents or care givers present. Prior to the pre-assessment, parents were asked to complete the written informed consent form (Appendix 2), and a supplemental information form (Appendix 6**).** The supplemental information form provided demographic information, diagnostic, and developmental history of the child. All the participants were video recorded during the motor assessments to ensure accurate scoring. All assessments were repeated at pre-test, post-test, and follow-up.

Measures

Motor Proficiency

Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), Short Form (Bruininks & Bruininks, 2010) is a standardized measure of fine and gross motor skills, which is derived from the full BOT-2 and is shorter and easier to administer (Bruininks & Bruininks, 2010). This measurement can be used for children and youth between 4-21 years of age and is used to identify individuals with mild to severe motor problems. This measure was used to provide scores for eight different areas of motor performance. These areas include: fine manual precision, fine manual integration, manual dexterity, bilateral coordination, balance, running, speed and agility, upper-limb coordination, and strength (Bruininks & Bruininks, 2010). This test was suited for this study since it has been used in several studies to evaluate gross and fine motor skills of children with ASD (Ghaziuddin & Butler, 1998; Ghaziuddin, Tsai, & Ghaziuddin, 1992).

Moreover, it is able to measure motor abilities that gymnastics intervention would target. Due to the young age of the participants, the short form of the assessment was suitable to use for this study.

Static and Dynamic Balance

The Static and Dynamic Balance components of Movement Assessment Battery for Children – Second Edition (MABC-2) (Henderson, Sugden, & Barnett, 2007) were used to assess static and dynamic balance. The MABC-2 is a standardized assessment for individuals between 3 years old and 16 years and 11 months old and is widely used to assess motor skills in children (Henderson et al., 2007). Static balance is referred as a position where the centre of mass remains within the base of support, whereas dynamic balance is defined as a position where the centre of mass moves away from the base of support (Henderson et al., 2007). Only the balance components of the test were used instead of applying the full measurement (Henderson et al., 2007). This test was used for this study because it is reliable, valid, and has been used to measure static balance for different population such as children with ASD, children with hand-eye coordination problems, and children with developmental coordination disorder (Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012; Forseth & Sigmundsson, 2003; Tsai, Wu, & Huang, 2008). In order to measure static balance, the participants were asked to stand on one leg with eyes open and arms held freely at the sides. The number of seconds, up to 30 in which the child maintained balance without any errors were recorded. Errors included winding/hooking the free leg around the standing leg, moving the standing leg, or touching floor with the free leg. Both right and left foot were tested (Henderson et al., 2007). The participants were allowed to perform two trails for each leg, but if they perform the task for 30 seconds at the first trial, the second trial was not performed. Both trials were recorded, but only the best time was used for statistical analysis (Henderson et al., 2007). Dynamic components of MABC-2 consisted of two different assessments. The first was heel-to-toe walking forwards on a line. The steps were considered correct, if the whole foot was on the line (Henderson et al., 2007). All participants completed this task. The other test was jumping or hopping on the mats provided by the assessment protocol (Henderson et al., 2007). Based on MABC-2 protocol, two-feet jumping on the mats was conducted for the participants under the age of seven, and hopping was conducted for those participants between seven and nine years of age (Henderson et al., 2007). Jumping was conducted with two feet, and the participants did not have to perform consecutive jumps, whereas hopping was performed on one foot, and the hops needed to be performed consecutively. Two trials were allowed for all components of these tests. Both right and left legs were tested (Henderson et al., 2007), and the participants were videotaped during the assessments to ensure the accuracy of scoring.

There was one participant under the age of seven in the gymnastics group, and two in fine motor group. These three participants performed jumping on the mats with two feet, instead of hopping on one leg. Therefore, four participants in the gymnastics group and three participants in fine motor group performed hopping on one foot on the mats, and one participant in the gymnastics group and two participants in fine motor group performed jumping on the mats.

Gymnastics Intervention

The gymnastics intervention started on March 18th and ended on April 28th 2016. During this period of six weeks, participants in the gymnastics group received the intervention once a week on Thursdays from 4:30 to 5:15. The intervention was facilitated and run by the principle investigator, with the assistance of a trained kinesiology graduate research assistant and a trained kinesiology undergraduate research assistant. The intervention took place at the UOIT Motor Behaviour and Physical Activity Lab. The principle investigator is a certified level two artistic gymnastics coach and certified level one trampoline coach with over 10 years of experience in coaching gymnastics to children of all age groups and ability levels. The ratio of child to instructor was 2:1 to ensure that each participant received sufficient support. Each session started with a 10 minute warm up which consisted of a short cardio exercise, followed by stretching. Next, the participants worked on different gymnastics activities for 30 minutes. Each session was completed with a five minute cool-down, which included various stretches (Gymnastics Canada Gymnastique, 2008). Understanding basic body positions is essential to teaching gymnastics and a core aspect of the introduction to gymnastics. Therefore, during all gymnastics sessions, basic body positions were practiced. These positions include tuck, pike, straddle, hollow, and arch, and were practiced in seated and standing positions during the first three weeks of the program. For the last three weeks, these positions were practiced with jumps. Exercises aiming to improve balance were performed during all gymnastics sessions. The exercises for static balance improvement included one leg stance in different body positions, such as having one leg straight, or bent, or having hands on hips or free, performing one leg stance on the floor, mats, or the balance beam. Exercises for dynamic balance improvement included jumping from mat to mat, hopping on one foot from mat to mat, walking on the line, or beam. Participants were asked to perform walking on the beam in different ways, such as forwards, sideways, or backwards. Based on the participant's level of ability, they also performed various animal walks on the beam such as bear and crab walking, bunny hopping, and horse galloping. Movements aimed at improving strength were performed during the whole intervention. Examples of the exercises were sit ups, a modified handstand where the participants kicked up towards a handstand. In order to improve flexibility, participants performed activities such as an overhead arm stretch, shoulder stretch, knee lunge, side lunge, butterfly stretch, straddle stretch, and crossover toe touch. In order to improve body coordination, forwards and backwards rolls were taught to the participants. The participants that gained sufficient skills performed more complex gymnastics skills such as cartwheels, which all require balance, body coordination and body awareness.

Table 1. Session overview for the gymnastics group

Activity	Time
Warm up (cardio and stretching exercises)	10 minutes
Different gymnastics exercises	30 minutes
Cool down (stretching exercises)	5 minutes

Fine Motor Intervention

Participants in fine motor group acted as the control group for this study. A fine motor intervention was suitable for the control group as previous literature has shown that children with ASD have impairments in fine motor skills (Bhat, Galloway, & Landa, 2012; LeBarton & Iverson, 2013; Lloyd, MacDonald, & Lord, 2013), therefore, they can benefit from fine motor activity interventions. There was also no overlap in activities with the gymnastics group and the participants in fine motor group attended the intervention for 45 minutes per week for a period of six weeks starting on March 18th and ending on April 28th 2016. This intervention took place on Thursdays from 5:30 to 6:15 and was facilitated by the principle investigator. One kinesiology graduate research assistant and one kinesiology undergraduate research assistant assisted with the intervention. The children created one or two different crafts, and took them home each week. All the participants sat at the same table and interaction between the participants was encouraged. The instructor provided positive feedback on the participants' creations and supported their interests. However, the participants in this group did not engage in any structured or facilitated gross motor activities. The child to instructor ratio was 2:1 for this group. The instructors assisted the children with any part of the craft activity that needed help with. The activities used during this intervention included drawing, colouring, working with the beads, making crafts with playdough, and folding papers.

Statistical Analyses

Descriptive characteristics were evaluated at baseline. An independent sample T-test was used to compare BOT-2 and balance assessments scores at baseline between the gymnastics and fine motor group to find out if there were any significant differences between the two groups at baseline. Repeated measures ANOVA were used to compare differences in BOT-2 and balance assessment scores between pre-test, post-test and follow-up within each group.

Results

Descriptive characteristics of the participants for gymnastics and fine motor group at baseline are presented in Table 2. There was no statistical difference between two groups in regards to their age, age of diagnosis, BOT-2 standard and raw scores, and static and dynamic balance scores (standing on one leg and walking on the line) at baseline.

Table 2. Baseline descriptive characteristics and motor proficiency by group.

Variable	Gymnastics (mean ± SD)	Fine Motor (mean ± SD)	p-value
Sex (male, female)	2 F, 3 M	1 F, 4 M	
Age (months)	100.00 ± 22.43	90.40 ± 16.80	0.94
Age of Diagnosis (months)	44.66 ± 26.37	37.00 ± 7.97	0.92
BOT-2 Overall Standard Score	33.80 ± 10.25	34.80 ± 14.34	0.83
BOT-2 Overall Raw Score	34.40 ± 25.60	32.6 ± 28.66	0.91
Static Balance (right leg)	15.40 ± 13.99	16.40 ± 15.32	0.92
Static Balance (left leg)	13.20 ± 15.38	11.20 ± 12.37	0.85
Dynamic Balance(walking on the line)	7.40 ± 7.16	6.40 ± 6.65	0.83

Significant motor impairments were evident for most of the participants at baseline. All participants had a standard score of 47 or below on BOT-2 total standard scores and all of them were ranked below 50%. Two participants in gymnastic group had motor skills that were well-below average, two of them below average, and one of them average at baseline (Bruininks & Bruininks, 2010). Two of the participants in fine motor group had motor skills of well-below average, one below average, and two were average at baseline according to the BOT-2 manual (Figures 2 and 3) (Bruininks & Bruininks, 2010). Only one participant in fine motor group had left hand as his dominant hand. The attendance for the gymnastics and fine motor group were 83.3 % and 96.6 %, respectively.

Figure 2. Baseline BOT-2 percentile rank for the gymnastics group

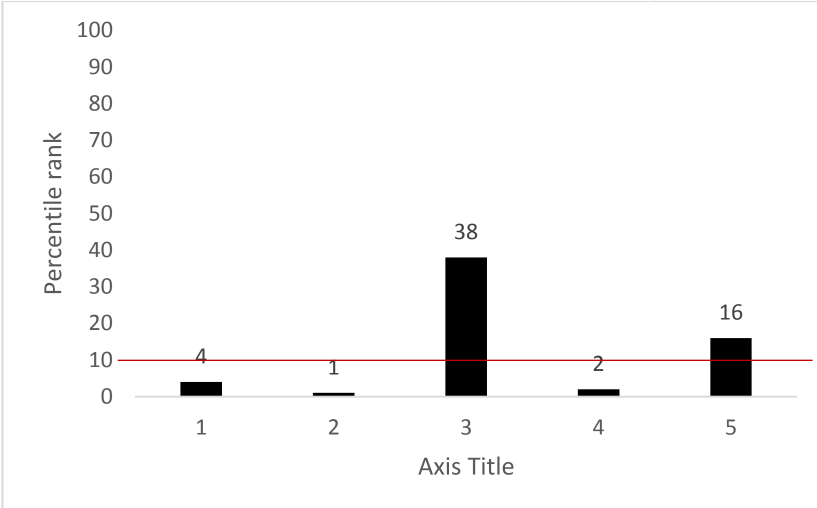
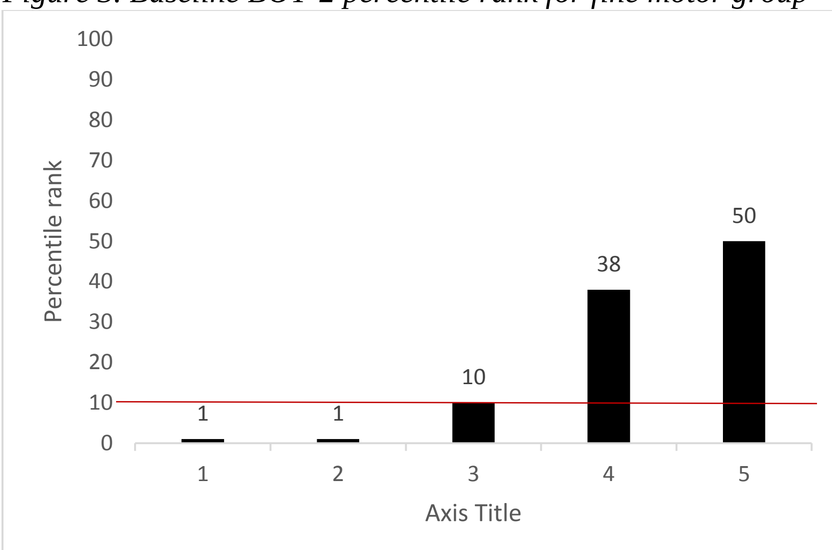


Figure 3. Baseline BOT-2 percentile rank for fine motor group



Overall raw and standard score group means for BOT-2 for gymnastics and fine motor groups at pre-test, post-test, and follow-up were measured and are presented in Figure 4 and 5. There were improvements from pre- to post- intervention and from pre-intervention to follow-up for gymnastics and fine motor groups.

Figure 4. Raw score group means on BOT-2 for gymnastics and fine motor groups at pre-test, post-test, and follow-up

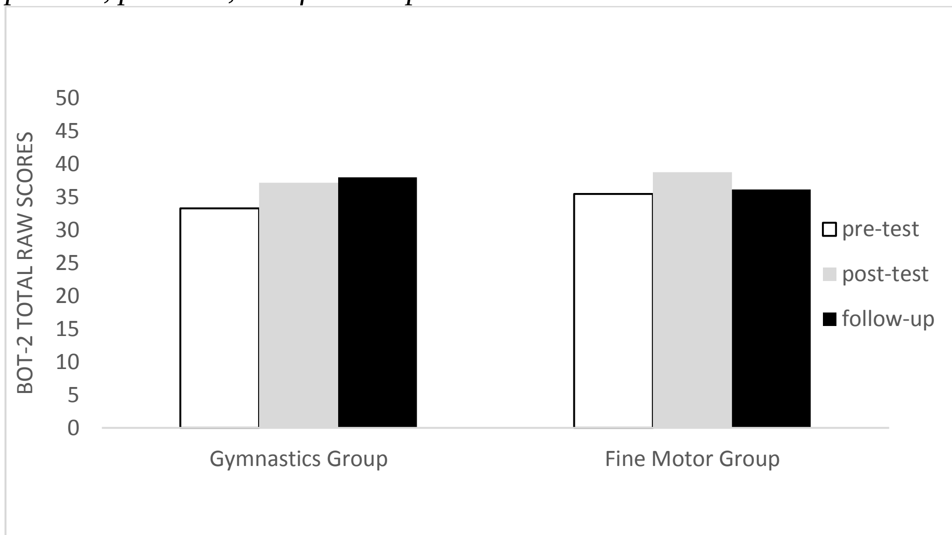
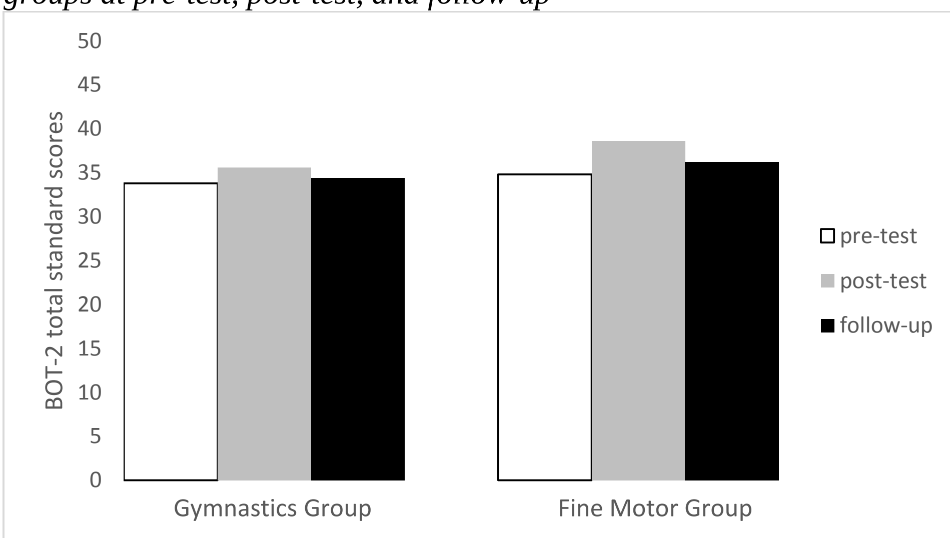


Figure 5. Standard score group means on total BOT-2 for gymnastics and fine motor groups at pre-test, post-test, and follow-up



Group standard and raw scores were calculated at pre-test, post-test, and follow-up for both groups and the results are presented in Table 3. Improvements were seen in raw scores for the gymnastics group from pre-test to post-test, and from post-test to follow-up. Group improvements were seen in raw scores from pre-test to post-test and from pre-test to follow-up for the fine motor group. Standard scores improved for the gymnastics group from pre-test to post-test, and from pre-test to follow-up, standard scores improvements were also seen for fine motor group from pre-test to post-test, and from pre-test to follow-up.

Table 3. Pre-test, post-test, and 4-week follow-up total raw and standard scores for BOT 2 by group

Variable	Group	*Pre-test Scores (mean ± SD)*	*Post-test Scores (mean ± SD)*	*Follow-up Scores (mean ± SD)*
BOT-2 Total Raw Score	Gymnastics	33.33 ± 23.05	37.20 ± 30.16	38.00 ± 28.34
	Fine Motor	35.50 ± 26.60	38.8 ± 30.02	36.20 ± 28.06
BOT-2 Total Standard Score	Gymnastics	33.80 ± 10.25	35.60 ± 12.97	34.40 ± 10.11
	Fine Motor	34.80 ± 14.34	38.60 ± 15.97	36.20 ± 15.64

Paired two sample t-test was used in order to calculate the differences within gymnastics and fine motor groups before and after the intervention and whether the differences were statistically significant (Table 4). The absolute change was also calculated for all BOT-2 subscales from pre- to post-intervention. Improvements were seen in the gymnastics group from pre-test to post-test in fine motor precision, fine motor integration, manual dexterity, balance, and strength. However the improvements were not statistically significant. No improvements were seen in gymnastics for upper-limb coordination from pre- to post-test. There was a decline in running, speed, and agility for the gymnastics group from pre-test to post-test (Absolute change=-0.40), as well as a decline in bilateral coordination (Absolute change=-0.60). Improvements were seen on all motor domains except for bilateral coordination in fine motor group from pre- to post-test, however they were not statistically significant. Significant differences in scores from pre-test to post-test were found in manual dexterity for fine motor group and significant decline in bilateral coordination ($p=0.03$) (Table 4).

Table 4. Results of paired two sample t-test from pre- to post-test on raw scores of BOT-2 subscales group. (Gymnastics group: n=5, fine motor group: n=5)

Variable	*Group*	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Absolute Change*	*p-value*	*Effect size*
Fine Motor Precision	Gymnastics	5.80 ± 4.71	6.8 ± 5.16	1.00	0.14	0.20
	Fine Motor	5.00 ± 4.69	6.60 ± 2.70	1.60	0.36	0.43
Fine Motor Integration	Gymnastics	4.80 ± 3.56	5.60 ± 3.78	0.80	0.24	0.21
	Fine Motor	5.80 ± 5.31	6.00 ± 5.47	0.20	0.37	0.03
Manual Dexterity	Gymnastics	2.00 ± 2.44	2.80 ± 2.94	0.80	0.09	0.29
	Fine Motor	2.40 ± 2.30	3.60 ± 1.81	1.20	0.03	0.58
Bilateral Coordination	Gymnastics	4.80 ± 3.19	4.20 ± 3.83	-0.60	0.37	-0.17
	Fine Motor	4.40 ± 3.57	4.20 ± 3.83	-0.20	0.03	-0.05
Balance	Gymnastics	5.20 ± 3.34	5.40 ± 3.28	0.20	0.37	0.06
	Fine Motor	4.20 ± 4.02	4.80 ± 4.38	0.60	0.37	0.14
Running, Speed & Agility	Gymnastics	4.60 ± 3.43	4.20 ± 3.76	-0.40	0.37	-0.11
	Fine Motor	3.80 ± 4.38	4.60 ± 4.21	0.80	0.49	0.18
Upper-limb Coordination	Gymnastics	4.60 ± 4.97	4.60 ± 6.30	0	1.00	0
	Fine Motor	5.40 ± 5.36	5.60± 5.77	0.20	0.92	0.03
Strength	Gymnastics	2.60 ± 2.30	3.00 ± 3.74	0.40	0.62	0.13
	Fine Motor	1.60 ± 3.04	3.40 ± 50	1.80	0.08	0.50

Paired two sample t-test was also used to calculate p-differences from pre-test to post-test for all BOT-2 subtests raw scores (Table 5). The absolute change was calculated for gymnastics and fine motor groups on BOT-2 subtests. Based on these results, with the exception of strength and agility, a positive improvement was noticed in the gymnastics group from pre to post-test on all BOT-2 subtests raw scores.

Table 5. Results of absolute change of scores from pre-test to post-test on raw scores of BOT-2 subtests by group

Variable	*Group*	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Absolute Change*	*p-value*	*Effect size*
Fine Manual Control	Gymnastics	10.60 ± 8.26	12.40 ± 8.90	1.80	0.18	0.2
	Fine Motor	11.40 ± 10.48	12.60 ± 7.63	1.20	0.53	0.13
Manual Coordination	Gymnastics	6.60 ± 7.05	7.4 ± 8.96	0.80	0.69	0.09
	Fine Motor	7.80 ± 7.04	9.20 ± 7.56	1.40	0.48	0.19
Body Coordination	Gymnastics	10.00 ± 6.48	10.20 ± 6.37	0.20	0.37	0.03
	Fine Motor	8.60 ± 7.50	9.00 ± 8.21	0.40	0.58	0.05
Strength and Agility	Gymnastics	7.20 ± 5.71	7.20 ± 7.39	0	1.00	0
	Fine Motor	7.00 ± 8.30	8.00 ± 7.87	1.00	0.60	0.12

The results from two-way analysis of variance with repeated measures on raw scores of BOT-2 subscales from pre- to post- to 4-week follow-up by group were calculated, and the findings are presented in Table 6. There were no significant group differences for any of the motor subscales, showing that the intervention type did not have a significant effect on the motor proficiency outcomes (Table 6). The results indicate that time had a significant effect on fine motor precision (p=0.02) (Table 6), but not on the other subscales.

The results of two-way analysis of variance with repeated measures on raw scores of BOT-2 subtests at pre- to post- to 4-week follow-up are presented in Table 7. There was no significant group by time interactions. (Table 7). Table 8 presents the results from a two-way analysis of variances with repeated measures on BOT-2 total standard scores. The results for each group are calculated by comparing pre to post to 4-week follow-up scores. There were no significant group differences, showing that the intervention type did not have an effect on the motor proficiency outcomes (Table 8). The results also indicate that time had a significant effect on total standard scores (p=0.03) (Table 8).

Results of pre-test, post-test, and follow-up static and dynamic balance (number of seconds for static balance and number of steps for dynamic balance) by group are presented in table 9. The results indicated a slight decline on right foot static balance in the gymnastics group from pre-test to post-test, and from post-test to follow-up, however, left foot static balance for the gymnastics group improved slightly from pre-test to post-test, but declined from post-test to follow-up (Table 9). The follow-up results, however, improved compared to the pre-test results. Static balance results for both feet improved from pre-test to post-test for the fine motor group, however, declined from post-test to follow-up on both feet (Table 9). the results for dynamic balance (walking on a line) indicated that the gymnastics group had a decline from pre-test to post-test, but the follow-up scores improved compared to both pre-test and post-test. The fine motor group scores improved from pre-test to post-test, but declined from post-test to follow-up. All the changes were non-significant (Table 9).

The results from two-way analysis of variance with repeated measures on raw scores of static and dynamic balance assessment from pre- to post- to 4-week follow-up by group were calculated, and the findings are presented in Table 10. There were no significant group differences for any of balance assessments, showing that the intervention type did not have an effect on the static or dynamic balance (Table 10). The results indicate that time did not have a significant effect on balance (Table 10). However, small improvements were seen in dynamic balance (number of hops on right and left foot) from pre-test to post-test, and from post-test to follow-up for the gymnastics group. Dynamic balance (number of hops on right foot) did not change from pre-test to post-test and from post-test to follow-up for the fine motor group. However, it slightly improved from pre-test to post-test for the left foot (Table 10).

Table 6. Pre-test, post-test, and follow-up raw scores of BOT-2 subscales by group

Variable	Group	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Follow-up Score (mean ± SD)*	*Group*	*Time*	*Group xTime*
Fine Motor Precision	Gymnastics	6.00 ± 4.24	6.80 ± 5.02	6.02 ± 5.21	F=0.24	F=4.72	F=0.91
	Fine Motor	5.33 ± 4.27	6.60 ± 2.70	5.60 ± 3.57	p=0.849	p =0.02	p =0.42
Fine Motor Integration	Gymnastics	5.50 ± 3.61	5.60 ± 3.54	5.4 ± 4.09	F=0.01	F=1.10	F=0.27
	Fine Motor	6.33 ± 4.92	6.00 ± 5.47	6.00 ± 5.47	p =0.91	p =0.35	p =0.76
Manual Dexterity	Gymnastics	2.00 ± 2.19	2.80 ± 2.87	3.6 ± 2.50	F=0.03	F=2.38	F=3.47
	Fine Motor	2.83 ± 2.31	3.60 ± 1.81	2.6 ± 1.94	p =0.85	p =0.12	p =0.05
Bilateral Coordination	Gymnastics	3.00 ± 3.28	4.2 ± 3.51	5.00 ± 2.91	F=0.05	F=0.23	F=1.52
	Fine Motor	4.83 ± 3.37	4.2 ± 3.83	4.20 ± 3.83	p =0.82	p =0.79	p =0.25
Balance	Gymnastics	5.00 ± 3.03	5.40 ± 2.96	5.6 ± 3.28	F=0.52	F=0.97	F=0.29
	Fine Motor	4.66 ± 3.77	4.80 ± 4.38	4.6 ± 3.57	p =0.49	p =0.40	p =0.75
Running, Speed & Agility	Gymnastics	3.83 ± 3.60	4.20 ± 3.14	4.40 ± 3.57	F=0.14	F=0.14	F=2.27
	Fine Motor	3.83 ± 3.92	4.60 ± 4.21	4.00 ± 4.06	p =0.71	p =0.86	p =0.13
Upper-limb Coordination	Gymnastics	4.16 ± 4.57	4.60 ± 5.24	5.20 ± 5.26	F=0.02	F=0.25	F=0.02
	Fine Motor	5.83 ± 4.91	5.60 ± 5.77	6.20 ± 4.38	p =0.86	p =0.77	p =0.97
Strength	Gymnastics	2.16 ± 2.31	3.00 ± 3.36	2.60 ± 3.57	F=0.76	F=1.93	F=1.16
	Fine Motor	1.83 ± 2.78	3.40 ± 4.09	3.00 ± 3.16	p =0.41	p =0.18	p =0.34

Table 7. Pre-test, post-test, and follow-up raw scores of BOT-2 subtests by group

Variable	Group	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Follow-up Score (mean ± SD)*	*Group*	*Time*	*Group x Time*
Fine Manual Control	Gymnastics Fine Motor	10.60 ± 8.26 11.40 ± 10.48	12.40 ± 8.90 12.60 ± 7.63	11.60 ± 9.18 11.60 ± 8.87	F=0.24 P=0.849	F=2.44 P=0.12	F=0.16 P=0.85
Manual Coordination	Gymnastics Fine Motor	6.60 ± 7.05 7.80 ± 7.04	7.4 ± 8.96 9.20 ± 7.56	8.80 ± 7.36 8.80 ± 6.30	F=0.01 P=0.91	F=0.39 P=0.68	F=0.70 P=0.51
Body Coordination	Gymnastics Fine Motor	10.00 ± 6.48 8.60 ± 7.50	10.2 ± 6.37 9.00 ± 8.21	10.60 ± 6.18 8.80 ± 7.25	F=0.03 P=0.85	F=0.45 P=0.64	F=0.29 P=0.75
Strength and Agility	Gymnastics Fine Motor	7.20 ± 5.71 7.00 ± 8.30	7.20 ± 7.39 8.00 ± 7.87	7.00 ± 7.00 7.00 ± 7.10	F=0.05 P=0.82	F=0.22 P=0.80	F=0.12 P=0.88

Table 8. Pre-test, post-test, and follow-up BOT-2 total standard scores by group

Variable	Group	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Follow-up Score (mean ± SD)*	*Group*	*Time*	*Group x Time*
BOT-2 Total Standard Score	Gymnastics Fine Motor	33.80 ± 10.25 34.80 ± 14.34	35.60 ± 12.97 38.6 ± 15.97	34.40 ± 10.11 36.20 ± 15.64	F=0.03 P=0.86	F=4.15 P=0.03	F=1.33 P=0.29

Table 9. Pre-test, post-test, and follow-up number of seconds for static balance and number of steps for dynamic balance by group

Variable	Group	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Follow-up Score (mean ± SD)*	*Group*	*Time*	*Group x Time*
Standing on right leg (# of seconds)	Gymnastics Fine Motor	15.40 ± 13.99 16.40 ± 15.32	14.80 ± 14.32 16.60 ± 15.05	13.40 ± 15.24 11.40 ± 12.32	F=0.15 P=0.70	F=2.30 P=0.13	F=0.79 P=0.47
Standing on left leg (# of seconds)	Gymnastics Fine Motor	13.20 ± 15.38 11.20 ± 12.37	14.20 ± 14.70 14.60 ± 14.82	13.80 ± 14.93 13.20 ± 11.98	F=0.32 P=0.58	F=1.63 P=0.22	F=0.62 P=0.54
Walking on the line (# of steps)	Gymnastics Fine Motor	7.40 ± 7.16 6.40 ± 6.65	7.20 ± 7.52 8.20 ± 7.66	8.00 ± 6.85 7.20 ± 7.52	F= 0.23 P= 0.64	F= 0.42 P= 0.66	F= 0.62 P= 0.54

Table 10. Pre-test, post-test, and follow-up number of hops on one foot for dynamic balance by group for participants over the age of seven. (Gymnastics group: n=4, Fine motor group: n=3)

Variable	Group	*Pre-test Score (mean ± SD)*	*Post-test Score (mean ± SD)*	*Follow-up score (mean ± SD)*	*Group*	*Time*	*Group x Time*
Dynamic Balance (# of hops on right foot)	Gymnastics Fine Motor	1.75 ± 2.36 3.33 ± 2.88	2.50 ± 2.88 3.33 ± 2.88	2.75 ± 2.62 3.33 ± 2.88	F=0.23 P=0.045	F=85 P=0.49	F=0.85 P=0.49
Dynamic Balance (# of hops on left foot)	Gymnastics Fine Motor	2.00 ± 2.44 2.66 ± 2.51	2.25 ± 2.21 3.33 ± 2.88	2.75 ± 2.62 3.33 ± 2.88	F=0.16 P=0.70	F=1.31 P=0.36	F=0.40 P=0.69

There was one participant under the age of seven in the gymnastics group, and two participants under the age of seven in in fine motor group. The one in the gymnastics group performed five correct jumps at pre-test, post-test, and follow-up. One participant in the fine motor group got the same number of jumps (5 correct jumps) , and the other participant in the fine motor group performed zero correct jumps at pre-test, post-test, and follow-up.

Discussion

The primary purpose of this study was to examine the effect of a gymnastics intervention on the motor skills of children ages five to nine with ASD, and compare it with a fine motor intervention. The secondary purpose of the study was to examine the effect of a gymnastics intervention on balance of children ages five to nine with ASD, and compare it with a fine motor intervention. Improvements in motor skills can have a positive effect on children's overall development (Alexander et al., 2014); therefore, it is important to implement motor skill interventions for children with ASD. Previous literature has found improvements in motor skills of children following motor skill interventions (Bremer, Balogh, & Lloyd, 2015; Bremer & Lloyd, 2016; Lang et al., 2010; Wuang et al., 2010). For example, Bremer et al. (2015) found improvements in motor skills of four year old children with ASD after receiving a fundamental motor skill intervention. However, no study had looked at the effect of a gymnastics intervention on motor skills of children with ASD. Therefore, this study helped to fill the gap in the scientific literature.

Baseline results indicated that out of the ten participants in the current study, seven had overall motor skills below average as measured by the BOT-2 (Bruininks & Bruininks, 2010); thus showing that most of the participants had motor skills that were below what would be expected for their age. This finding is consistent with the results from the previous studies that have found motor skill impairments in children with ASD (Lloyd et al., 2013; Staples & Reid, 2010; Whyatt & Craig, 2012) and further demonstrates the need to conduct interventions targeting motor skills in this population.

Gymnastics Group

Our results showed that there were small improvements in overall standard and raw scores for the gymnastics group immediately after receiving the intervention (Table 3). Upon comparing post-test results with follow-up results, it was revealed that there was a non-significant decline in total standard scores for the gymnastics group. It is not clear why the skills regressed. It is possible that the intervention might not have been long enough, or not have delivered a high enough dosage for retention. Future research should investigate various intensities of intervention as well as dosage. Overall, the children in the gymnastics group improved in most of the BOT-2 subtests and subscales following the intervention (Tables 4 and 5). Many studies have provided evidence for motor impairments and delays in motor milestones associated with a diagnosis of ASD (Lloyd et al., 2013; Staples & Reid, 2010; Whyatt & Craig, 2012). Since these skills are used in many leisure and physical activities, poor motor skills can affect the children's ability to participate in different games and sports, and may cause the children to withdraw from those activities (Todd, 2012). Therefore, any improvement in motor skills can be advantageous for children with ASD and have real life benefits for them.

The type of gymnastics exercises selected for this study may have been a factor in the improvements in the results. Circuit training, which consists of a group of different exercises that are completed one after the other was used during the intervention. Therefore, the children learned basic gymnastics skills by rotating through different stations (Donham-Foutch, 2007). Since circuit training requires the children to constantly move from one station to another, it decreases the time of sitting and reduces inactivity. This was also very beneficial because of the limited amount of time available to conduct the intervention. The small improvements may also be reflective of the simple gymnastics exercises taught during the intervention. The exercises included basic skills and simple sequences and gradually different skills were added to the previous ones. Furthermore, research by Todd (2012) has demonstrated that in order to minimize the challenges that children with ASD experience, motor skills should be instructed in separate smaller segments, as a result, each gymnastics skill was divided into simple sequences. It was ensured that prior to progressing onto the next action, the children were comfortable with the previous movements. For instance, in order to teach the participants how to do a forwards roll, the forwards roll was taught in this manner: Squatting down and tucking the chin in, Grabbing the knees and performing rock and rolls (rocking back and forth on the back), rock and rolls to a squat position, rock and rolls to stand up, starting the roll from elevation (few folding mats were used for this stage, so that the participants place their feet at a higher place), and finally they would try a forwards roll. Given the poor motor skills in children with ASD, some of the participants did not perform the final step of the forwards roll. Another example would be exercises on the balance beam. A floor balance beam was used for the intervention. First, the participants were asked to do the exercises on a line, and then they would try them on the beam. They were asked to walk forwards either by themselves, or using help from the principal investigator or the helpers, after that, they would try walking sideways, and then backwards; if they could master these steps, they were asked to perform animal walks, hops, and runs on the beam. Despite carefully designing the curriculum and implementing it in a systematic fashion, we did not see significant improvements in motor skills in this group, which could be due to the small dosage of the program or lack of enough gymnastics equipment.

Previous studies have shown impairments in balance and postural control in children with ASD (Green et al., 2009; Memari et al., 2014; Miyahara et al., 1997). Poor balance can have a negative effect on motor skills, and can further lead to lack of participation in leisure activities (Silkwood-Sherer et al., 2012). Therefore, it is important to implement interventions that aim to improve balance in children with ASD. Enhanced balance and postural control is among the benefits of participation in gymnastics. Gymnasts usually have better balance and a more stable posture compared to those who do not participate in any gymnastics activities, therefore, it would be beneficial for children with ASD to participate in gymnastics activities, so that the exercises can help them improve their balance and postural control.

The pre-test to post-test, as well as the post-test to follow-up evaluations from the static balance results indicated a slight decline on right foot static balance in the gymnastics group (Table 9). The assessment was very easy for some participants while difficult for others. The two older participants received a full score for the static balance assessments at pre-test, post-test, and follow-up, whereas the younger participants had difficulties performing the task. Such findings can be due to the fact that the same evaluation from the MABC-2 for three to six year olds was used for all the participants including the older ones. Therefore, the full scores achieved by the older children does not necessarily mean that their static balance was not impaired for their age. Using the one-board balance assessment from the static balance test for 7-10 year old children in the MABC-2, could potentially have led to the older participants achieving different results. Moreover, the two participants who scored the highest were the only girls in the gymnastics group. This finding is in line with the literature indicating better postural control of girls than boys of the same age (Alex & Lin, 2007) (Nolan, Grigorenko, & Thorstensson, 2005).

Left foot static balance for the gymnastics group improved slightly from pre-test to post-test, but declined from post-test to follow-up (Table 9). The follow-up results, however, were higher than the pre-test results. Since all participants in the gymnastics group were right foot dominant, these results indicate that the intervention may have had a better effect on the non-dominant foot. During the intervention the children were allowed to practice the static balance exercises (such as standing on one foot while the free leg is straight or bent, or balancing on two hands and one knee on the floor) on any feet they preferred and they were not forced to try it on s specific feet. Therefore the results can further suggest that in order to improve static balance for the dominant foot, there should be more exercises targeting the dominant foot separately from the non-dominant foot. The results also indicate that more exercises are needed on static balance in general. The possible reason why we did not see significant improvements could be because the participants were mostly moving from one station to the other, therefore, they did not focus on activities specifically targeting their static balance. More research is needed on looking at the effect of static gymnastics exercises on static balance of children with ASD.

Our findings are in contrast to findings reported in the literature regarding the effect of motor skills and balance interventions on balance and postural control (Behrens, Mau-Moeller, Wassermann, Bader, & Bruhn, 2015; Heitkamp, Horstmann, Mayer, Weller, & Dickhuth, 2001). Previous studies have reported a positive effect on balance following motor skill and physical activity-based interventions (Behrens et al., 2015; Heitkamp et al., 2001; Wuang et al., 2010), but in such studies, the participants were adolescents and adults, and did not have a diagnosis of ASD. This can further show that these interventions might be more effective for older populations, and those without ASD; a different population than the one we had for this study (Behrens et al., 2015; Heitkamp et al., 2001).

Results from the dynamic balance assessment showed small improvements in the gymnastics group for both hopping on right and left foot from pre-test to post-test and from post-test to follow-up (Table 10). These small improvements can be the result of exercises that targeted dynamic balance. However the results for dynamic balance (walking on a line) indicated that the gymnastics group had a decline from pre-test to post-test, but the follow-up scores improved compared to both pre-test and post-test. It is possible that familiarity to the test was a factor; it is also possible that the effects of the intervention may not appear immediately, instead they may appear after a period of time. Previous research has shown that children with ASD usually have poor balance (Bhat et al., 2012; Bhat et al., 2011; Fournier et al., 2010; MacDonald et al., 2013), further preventing children from participating in physical activity and active play. As a result, it is hopeful that even such small improvements can have a positive effect on physical and social development of the children with ASD.

Fine Motor Group

The fine motor group acted as our control group. Therefore, it was not expected to see any significant changes in gross motor skills for this group following the intervention. However, the results for the fine motor group indicated small improvements on total motor skill standard and raw scores, as well as most of the BOT-2 subtests and subscales following the intervention.

Children with ASD have been reported to have poor fine motor skills and can improve such skills through fine motor skill interventions (Ohl et al., 2013; Provost et al., 2007). Besides a general motor deficit, some studies have more specifically provided evidence for impairments in manual dexterity in children with ASD (Green et al., 2002; Green et al., 2009; Hilton et al., 2007; Miyahara et al., 1997). Manual dexterity is defined as the ability to perform coordinated hand and finger movements, which can include finger control in grasping and manipulating small items (Térémetz, Colle, Hamdoun, Maier, & Lindberg, 2015). Our results show that there was a significant improvement in manual dexterity over time from pre-test to post-test for the fine motor group. During the fine motor intervention, participants practiced activities such as drawing, making crafts with play-dough, colouring, and folding papers, which can potentially be the reason for the significant improvement in manual dexterity. Improving manual dexterity can be beneficial for children with ASD, because it can help them with day to day activities such as feeding oneself, zippering, buttoning, and getting dressed, thus, helping them have a more independent life. Moreover, such improvements can be important for children with ASD, as there is a correlation between the levels of manual dexterity and social skills in children with ASD (Shogo. et al., 2014). Shogo. et al. (2014) found that manual dexterity of 7-16 year old children with ASD was interrelated with the severity of their social skills. Such findings further show the importance of implementing fine motor interventions that target to improve fine motor skills in children with ASD.

There was a significant decline in bilateral coordination in the fine motor group from pre-test to post test in this study. It is not clear why there was a regression. The BOT-2 bilateral coordination items included Jumping in Place-Same Side Synchronized and Tapping Feet and Fingers- Same Side Synchronized. No activity similar to the items of the test was used during the fine motor intervention, which could be the cause of the decline in the results. In addition, attention difficulties are common among children with ASD (Murray, Lesser, & Lawson, 2005), thus short attention span can also be one potential factor that may have contributed to the poor results in post-test. Wuang et al. (2010) similarly found a decline in bilateral coordination of children participating in a simulated developmental horse-riding program from post-test to follow-up. More research is needed on activities that can improve bilateral coordination in children with ASD.

The fine motor group had non-significant improvements on both right and left foot static balance from pre-test to post-test. Following the intervention there was a significant improvement in manual dexterity in the fine motor group, which is consistent with a study conducted by Flatters et al. (2014). The authors of the study suggested that there is a correlation between postural stability and manual dexterity in children 3-11 years old with

ASD. This shows the importance of implementing interventions to improve manual dexterity, because as shown, such improvements might also result in increased postural stability in children with ASD. However, more research is needed on this link. Postural stability is a fundamental aspect of motor ability and acts as the basis for many motor tasks. Moreover, an inability to properly balance in leisure and daily life activities can have additional social impacts on the children, their ability to interact with their peers, and may lead to being socially isolated (Travers, Powell, Klinger, & Klinger, 2013). As a result, implementing interventions that aim to improve postural stability in children with ASD is very important.

Similar to the right foot static balance for the gymnastics group, static balance results had a non-significant decline from post-test to follow-up for the fine motor group on both feet (Table 9). However, the follow-up scores were still higher than pre-test scores for left foot, but for the right foot, the follow-up scores were lower than the pre-test scores. There was a non-significant decline in fine motor group for dynamic balance (walking on the line) from pre-test to post-test, and from post-test to follow-up. The follow-up scores were, however, higher than pre-test scores. Our finding is not unexpected, as balance was not targeted in the fine motor intervention, and there is no link between fine motor skills and dynamic balance in the literature.

The participants in the fine motor group scored the same for hopping on right foot on all three assessments, and made small improvements on hopping on left foot from pre-test to post-test, but the results from post-test to follow-up remained the same (Table 10). Such results were expected from the fine motor group, as there were no activities during the fine motor intervention aiming to improve dynamic balance of the participants. Jumping with two feet results did not change for the participants on the three assessments, which can show that the interventions did not have any effect on their jumping and dynamic balance, showing that fine motor intervention might not have any effect on dynamic balance in children with ASD.

In summary, the gymnastics group showed small improvements in overall standard and raw scores for their motor skills following the intervention, as well as non-significant improvements in most BOT-2 subtests and subscales. There were also non–significant improvements in their dynamic balance and left foot static balance, and a small decline on right foot static balance after receiving the intervention. Gymnastics can offer various locomotive, stability, and body awareness for children (Gymnastics Canada Gymnastique, 2008). Activities provided in gymnastics can help children develop the foundation for motor skills (Coelho, 2010), As a result it is still suggested that gymnastics interventions can help children with ASD improve their motor skills and balance, as they can develop the foundation needed for motor skills development.

There were small improvements on overall motor skills standard and raw scores after the intervention for the fine motor group. There were also non-significant improvements in most of the BOT-2 subtests and subscales. Moreover, there was a significant improvement in manual dexterity following the intervention. This improvement can help the children with ASD with their daily activities, therefore, can help them be more independent. There were small improvements on right and left foot static balance from pre-test to post-test, but they slightly declined from post-test to follow-up. There were no changes in dynamic balance (hopping on right foot as well as jumping on two feet) on any of the three assessments, however, the left foot dynamic balance (hopping on left foot) slightly improved following the intervention. Moreover, there was a small improvement on dynamic balance (walking on the line) following the intervention. The fine motor group was the control group for the study, as a result, no changes in gross motor skills and balance was expected for the participants in this group.

Gymnastics LTAD

Gymnastics Canada tries to positively impact on the quality of the gymnastics experience for all participants regardless of the level of the ability. In order to achieve a fully integrated and unified Canadian gymnastics system, children should be encouraged to participate in gymnastics activities regardless of their ability levels. Understanding and respecting the principles of LTAD can help with making decisions about the future directions of gymnastics in Canada, which includes inclusion of children regardless of their gender, ability or disability. However there are some challenges in this pathway. One of these challenges is making formal links with organizations that offer gymnastics programs for individuals with disabilities such as Special Olympics Canada. Such partnerships could create more opportunities for participation in gymnastics programs for individuals with disabilities. In addition, Gymnastics Canada should promote this nationally and provide incentives for applying best practice strategies, such as increasing the awareness and understanding of how we can create more inclusive programs for individuals with all levels of abilities. Consequently, gymnastics clubs should provide support by offering programs for individuals with disabilities (Gymnastics Canada Gymnastique, 2008). Presently, most of the gymnastics programs offered for individuals with disabilities are intended for people with an intellectual disability, not for children with ASD (Gymnastics Canada Gymnastique, 2008b). In addition, children with intellectual disabilities are sometimes fully integrated into local recreational gymnastics programs, whereas children with ASD are not (Gymnastics Canada Gymnastique, 2008).

Such programs are offered at different levels of formality and participation. Some of these programs are affiliated with Special Olympics Canada (Balyi et al., 2013).

In summary, in order to fully implement the principles of LTAD, gymnastics clubs should give a higher emphasis on Gymnastics-for-All in their programs. Gymnastics-for-All consist of non-competitive gymnastics activities, and can be the main area for the participation of individuals with disabilities. Although these programs provide the structure for all types of gymnastics, they are usually neglected in gymnastics clubs, and need more attention, funding, and resources. For instance, provincial/territorial governments must endorse LTAD framework, and partner with Gymnastics Canada, providing incentives to gymnastics organizations. The gymnastics clubs should also be supported to offer programs for individuals with disabilities. In addition, gymnastics coaches should be more aware and understanding of how to create gymnastics programs that are more inclusive, and should be specifically trained to work with athletes with disabilities (Gymnastics Canada Gymnastique, 2008)

Strengths and Limitations

As with any study there are strengths and limitations that must be addressed. A strength of this study is the control group, allowing for gymnastics intervention and fine motor intervention to be compared. Studies on motor skills of children with ASD largely compare motor skills of a group of children with ASD in relation to a group of children with other disorders or developmental delays (Provost et al., 2007; Staples & Reid, 2010; Whyatt & Craig, 2012). However, in this study the fine motor group consisted of children with ASD, allowing us to indicate how the interventions impact children with ASD compared to another group of children with ASD, as opposed to those with other disorders. In addition, the participants in this study had different levels of ability, which was in line with LTAD principle of inclusion of children with different levels of abilities. Another positive feature of this study was that it was provided free of charge and those who participated did not have to be on a waiting list. In addition, compared to regular gymnastics programs where the instructor to child ratio may be as high as one to eight, in this study the instructor to child ratio was 1:2.

A significant limitation for the study was the small sample size and small dosage of the offered activities. A larger sample size, and offering the intervention more than once a week, might give us a better indication of the effectiveness of the interventions, however this was not feasible in the constraint of this study. Moreover, the examiner was not blind to the group to which the participants were assigned and the parents were not given activities to work with children at home based on the group they were assigned to. In addition, implementing the intervention in a gymnastics club might also be beneficial to allow for more gymnastics equipment to be used, and a larger variety of gymnastics activities to be performed. However, a large gymnastics facility may not be suitable due to the sensory challenges children with ASD often experience. Given the simplicity of the gymnastics activities taught in this intervention, the multi-purpose space was a suitable space.

The lack of statistically significant change in motor skills can be due to our small sample size. It may also be because of poor attendance in the gymnastics group, as two of the participants only attended 50% of the intervention. One of the participants was also late by two weeks in completing both the post-test and follow-up due to personal issues, which could also be a factor to the lack of differences found. It may also be due to the fact that the gymnastics intervention did not run in a gymnastics setting, however running the intervention in a gymnastics club may have some disadvantages, such as causing distraction for the children. Gymnastics Canada Gymnastique (2008) suggested one class per week for one to an hour and a half for six to eight year old girls and six to nine year old boys (Gymnastics Canada Gymnastique, 2008). This duration is obtained from the Fun, Fitness, and Fundamental Movement Patterns LTAD stage. However, since the abilities of our participants were closer to the Active Start stage, the amount of time used for our study (one class per week for 45 minutes) was derived from the amount of time suggested in the Active Start stage in LTAD model which was 45-60 minutes per week for four to six year old children (Gymnastics Canada Gymnastique, 2008). Using the suggested amount of time for Fundamental Movement Patterns stage might have resulted in better results and this needs to be studied further.

In most of the gymnastics clubs there are different groups of children, which can cause overstimulation for many children with ASD. As a result, since children with ASD often experience sensory challenges (Rogers, Hepburn, & Wehner, 2003), it is difficult for them to participate in regular gymnastics classes. Thus, this intervention gave the participants an opportunity to participate in a gymnastics program where the environment was built to minimize sensory overloads for them, increasing their opportunity to participate.

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Chapter 4: Thesis Conclusions

Summary

Autism Spectrum Disorder (ASD) is a condition characterized by deficits in communication and social skills, and the presence of restricted and repetitive patterns of behaviour, interests, or activities (American Psychiatric Association, 2013). In addition to these three main characteristics, children with ASD also experience difficulties in gross and fine motor skills (Bhat, Landa, & Galloway, 2011; Liu & Breslin, 2013; Lloyd, MacDonald, & Lord, 2013; MacDonald, Lord, & Ulrich, 2013). The impairments in motor skills often start at an early age, but are also observable in childhood and adulthood (Ament et al., 2015; Bhat et al., 2011; Ming, Brimacombe, & Wagner, 2007). In fact, research has shown that as children with ASD get older, sometimes their motor skills worsen (Landa & Garrett-Mayer, 2006). This decline in motor skills can affect the daily living of the children, because as they get older, they use motor skills to play with other children, interact with other individuals, and participate in leisure activities (Hilton et al., 2007; Twarek, Cihon, & Eshleman, 2010). Therefore, poor motor skills can affect the children's social relationships and overall development (Alexander, Frohlich, & Fusco, 2014). As a result, it is important to designs interventions and programs for children with ASD that aim to improve motor skills in this population. However, the primary focus of most of the intervention for children with ASD has been the core challenges in communicative, social, and behavioural skills (Matson & Smith, 2008).

Research has also indicated that children with ASD experience poor balance and postural control (Memari, Ghanouni, Shayestehfar, & Ghaheri, 2014; Minshew, Sung, Jones, & Furman, 2004). Balance is the essential element for motor development in the children (Fabbri-Destro, Gizzonio, & Avanzini, 2013). Poor balance can cause difficulties with learning new skills, therefore it can affect participation in the playground and at school, which can further result in the exclusion of the children from interaction with others, and participating in social activities (Silkwood-Sherer, Killian, Long, & Martin, 2012). Therefore, there is a need to conduct interventions aiming to improve balance in children with ASD.

The primary objective of the current study was to investigate the effectiveness of a gymnastics intervention on motor skills of children ages five to nine with ASD and compare it with a fine motor intervention. The secondary purpose of the study was to investigate the effectiveness of a gymnastics intervention on static and dynamic balance of children ages five to nine with ASD and compare it with a fine motor intervention. Baseline results showed that seven of the ten participants had below average motor skills, which is consistent with the literature indicating poor motor skills in children with ASD (Lloyd et al., 2013; Staples & Reid, 2010; Whyatt & Craig, 2012). The results from this study demonstrated that a gymnastics intervention for five to nine year old children with ASD can make non-significant improvements in motor skills of children with ASD, as well as non-significant improvements in dynamic balance, and left foot static balance.

Gymnastics Intervention and the WHO-ICF

The WHO-ICF provides a framework and standard language to describe health and health related states (WHO, 2001). The WHO-ICF framework takes into consideration the reciprocal relationships among three concepts which are body function and structure, activity, and participation; and considers a role for environmental and personal factors as well. According to this model, the individual experience of functioning is not considered as the consequence of a disability or disease, but the result of the dynamic interaction between health conditions, environmental factors, and personal factors, as well as incorporating domains of activity and participation. Therefore, for a person with a disability, all components of the disability are important, as any of them can interact with another (WHO, 2001)

The purpose of conducting a gymnastics intervention was to improve motor skills and balance of children ages five to nine with ASD, which may further allow for more participation in activities such as recreational and leisure activities, that require proficient motor skills. The activity factor means the execution of a task or action by the individual. For children with ASD activities are often limited due to poor motor skills and balance (Whyatt & Craig, 2012). The activity section of the WHO-ICF was relevant to the current study, because the gymnastics exercises provided during the gymnastics intervention aimed to improve gross motor skills and balance of the participants. The activity stage was where we expected to see changes in this study. In addition, the activities in the fine motor intervention targeted to improve fine motor skills in the participants. The participation section of the model means involvement of the participants outside the intervention and in real life situations and using their 'activity' level skills in those situations. In this study, an example for participation would be when the child uses the skills that he/she has learned during the intervention, outside of the intervention setting, such as a playground, school, or home. It is hoped that by performing the skills that children learned during the intervention more regularly, the skills can turn into permanent skills. The permanent skills can further encourage performing more motor skills, more participation in sport and recreational activities, as well as activities of daily living; thus improving the 'participation' section. In addition, 'personal' factors may involve age, sex, motivation and support, lifestyles, and ethnicity; the environmental factors can include different settings which may affect the learning of the participants. In order to improve the participation, it is important to develop the activity level of the participants. We hypothesized that by improving the 'activity' factor of the model, we will be able to see improvements in 'participation' of the children. Personal and environmental factors can also affect the development of the activity. For example, having too many participants and loud noise as environmental factors were avoided during the intervention, however, personal and environmental factors were not the focus of the current study.

LTAD and Gymnastics

Gymnastics Canada's mission is to promote and provide positive and diverse gymnastics experiences. Therefore, they aim to positively impact on the quality of the gymnastics experience for all participants regardless of the level of their ability (Gymnastics Canada Gymnastique, 2008). In order to achieve a fully integrated and unified Canadian gymnastics system, everyone who is part of the system should work together. For example, given the high prevalence of ASD, Gymnastics Canada should allocate sections of the gymnastics coaching courses towards increasing awareness about disabilities such as ASD, as well as offering strategies on how to work with individuals with disabilities, specifically with ASD. In addition, gymnastics organizations should create more opportunities for participation in gymnastics programs for individuals with disabilities, coaches and parents should understand the principles of LTAD (Gymnastics Canada Gymnastique, 2008), and children should be encouraged to participate in gymnastics activities with any levels of ability.

Understanding and respecting the principles of LTAD can help with making decisions about the future directions of gymnastics in Canada, to include athletes with disabilities (Gymnastics Canada Gymnastique, 2008). Presently, most of the gymnastics programs offered for individuals with disabilities are intended for people with an intellectual disability, not for children with ASD (Gymnastics Canada Gymnastique, 2008). Although intellectual disability can co-occur with ASD, not all children with ASD have an intellectual disability. The needs of children with ASD differ from those with an intellectual disability. For example, gymnastics programs designed specifically for children with an intellectual disability might not be very helpful for those with ASD. In addition, children with an intellectual disability are sometimes fully integrated into local recreational gymnastics programs, whereas children with ASD are not (Gymnastics Canada Gymnastique, 2008). As a result, there is a need to conduct gymnastics programs for children with ASD. In order to do that, gymnastics programs need to be specifically designed based on the needs of children with ASD. For example, each skill needs to be taught in basic segments, having too many children at the gym, loud noise, and bright lighting should also be avoid in the gym, which can all help the children work on different motor skills, interact with one another, and help improve the children’s overall development based on their specific needs (Kolehmainen et al., 2011).

In summary, in order to fully implement the principles of LTAD, gymnastics clubs should give a higher emphasis on Gymnastics-for-All in their programs. Gymnastics-for-All programs consist of non-competitive gymnastics activities, and can be the main area for the participation of individuals with disabilities. Although these programs provide the structure for all types of gymnastics, they need more attention, funding, and resources (Gymnastics Canada Gymnastique, 2008). For instance, provincial/territorial governments should encourage the gymnastics facilities to use LTAD framework and provide more Gymnastics-for-All programs for all the children. In addition, gymnastics coaches should be more aware and understanding of how to create gymnastics programs that are more inclusive. Furthermore, the coaches should be specifically trained to work with athletes with disabilities and be aware of their needs in order to offer the most suitable programs for those children (Gymnastics Canada Gymnastique, 2008).

Recommendations

Based on the findings from this study, there should be modifications to the LTAD model for gymnastics when it is implemented for children with disabilities. Some children with disabilities are placed at a stage of the LTAD based on their chronological age, whereas their level of ability would be the same as children in the lower ages. Therefore, it is suggested that children with disabilities be placed in programs based on their ability or skill level, rather than age. For instance, if a child with ASD is supposed to be in the Fundamental Movement Patterns stage by age-based definitions, the gymnastics activities selected for them may need to be derived from the lower stage of LTAD, which is the Active Start stage. Due to the fact that motor impairments are often seen among children with ASD, it could be more helpful for them to receive more hours of gymnastics classes, therefore, the dosage of the program should be selected based on their age, which would be the Fundamental Movement Patterns Stage in this case.

As a result of the nature of ASD, having a small group of individuals with ASD may be more appropriate than working in large groups or competitive teams (Menear & Smith, 2008). Therefore, when gymnastics clubs implement gymnastics programs for children with ASD, it would be beneficial to keep a low instructor to child ratio. They should also make the environment less stimulating by reducing the number of children in the gym and minimizing the noise. Moreover, as children with TD go through a gymnastics level system in gymnastics programs, a modified level system which is specifically designed for children with disabilities should be developed, so that those children can have the feeling of accomplishment after completing each gymnastics session.

Conclusion

In conclusion, the results from this study indicate that a gymnastics intervention that runs once a week for a six week period can make small improvements in motor skills and some components of balance of children ages five to nine with ASD. The findings also show that a gymnastics intervention that runs once a week for a six week period may not be long enough to result in significant improvements in motor skills and balance of children with ASD. Additionally, a fine motor intervention can be effective at improving manual dexterity for children ages five to nine with ASD. Our results give us a better understanding on how to conduct gymnastics interventions more efficiently for children with ASD, in terms of dosage, duration, and the type of exercises being used during the intervention. The results also provide us with a potential direction for how to modify the LTAD framework while using it for children with ASD. To the best of our knowledge, this is the first study to investigate the effectiveness of a gymnastics intervention on motor skills and balance of children ages five to nine with ASD; as a result, the findings make a significant contribution to the motor skill interventions literature for children with ASD. It is recommended conducting more gymnastics interventions with higher dosage and duration for children with ASD in the future.

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SECTION 5: APPENDICES

Appendix 1: Certificate of Approval from the University of Ontario Institute of Technology Research Ethics Board

Date:	*January 27, 2016*
To:	*Shahrzad Pezhman*
From:	*Shirley Van Nuland, REB Chair*
REB # & Title:	*(15-074) Investigating the Effectiveness of a Gymnastics Intervention on Motor Skills and Balance of Children Between the Ages of Five to Nine with Autism Spectrum Disorder*
Decision:	*APPROVED (January 24th, 2016)*
Current Expiry:	***January 01, 2017***

Notwithstanding this approval, you are required to obtain/submit, to UOIT's Research Ethics Board, any relevant approvals/permissions required, prior to commencement of this project.

The University of Ontario, Institute of Technology Research Ethics Board (REB) has reviewed and approved the research proposal cited above. This application has been reviewed to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS2 (2014)) and the UOIT Research Ethics Policy and Procedures. You are required to adhere to the protocol as last reviewed and approved by the REB

Appendix 2: Parent/ Guardian Informed Consent Form for Study Participation

Informed Consent:

Gymnastics and Fine Motor Interventions for Children ages 5-9 with Autism Spectrum Disorder

Date: March 10, 2016

Investigators:

Shahrzad Pezhman	Faculty of Health Sciences University of Ontario Institute of Technology 905-721-8668, ext. 5988 shahrzad.pezhman@uoit.ca
Dr. Meghann Lloyd	Faculty of Health Sciences University of Ontario Institute of Technology 905-721-8668, ext. 5308 meghann.lloyd@uoit.ca

Dear Parents,

You and your child are invited to participate in a voluntary research study. The purpose of this study is to investigate the effectiveness of a gymnastics intervention compared to a fine motor intervention for children ages 5-9 with Autism Spectrum Disorder (ASD). The children will be randomized into either gymnastics or fine motor intervention group. The children in gymnastics group will receive gymnastics lessons once a week, for six weeks. Each session will take 45 minutes. The children in fine motor skills group will receive fine motor skills once a week, for six weeks. Each session will take 45 minutes.

Why is this work important?

Children with ASD often have poor gross and fine motor skills, as a result there is a need to start motor skill interventions for these children at an early age. These children also experience challenges such as low levels of balance, postural control, and motor coordination. Since postural control is important for achieving a typical motor development, and can make an improvement in overall motor skills for children with ASD, it is essential to create interventions that target balance and postural control improvement for this population.

Gymnastics is a sport that can develop motor skills and help individuals move their bodies efficiently in everyday life. There are several other benefits of participation in gymnastics. For example it helps children develop better coordination, body awareness, balance, and body posture as well as better flexibility, strength, and agility. In gymnastics children work on basic movement patterns such as jumping, landing, and running. In contrast with competitive gymnastic, for recreational gymnastics, participants do not require to have high levels of training, therefore it is possible to teach it easily to children.

Children with ASD often have poor fine motor skills, as a result, the children in the fine motor group will benefit from receiving fine motor skills lessons. These lessons will focus on improving fine motor precision, fine motor integration, and manual dexterity. These skills will be practiced through activities such as cutting papers, stinging beads, copying different shapes, colouring, and playing with legos.

The purpose of this study is to investigate whether there is any benefit for children ages 5-9 with ASD in terms of gross and fine motor skills, as well as balance after receiving a gymnastics or fine motor skill intervention.

Study Procedure

This study includes assessment of gross and fine motor skills, as well as static and dynamic balance of the participants in both gymnastics and fine motor skills groups. Prior to the intervention, we will ask you to complete a few questionnaires in order to provide demographic and background information about your child. It will take approximately 30 minutes to complete the questionnaires. They will be provided to you on-site at the pre-test. Upon arrival to the pre-test, we will measure your child's gross and fine motor skills and balance and will ask you and your child a series of questions. The children will be randomized into gymnastics or fine motor group. Your child will be video recorded during gross and fine motor testing for pre-test, post-test, and follow up. If you consent, the data collected from your child may also be used for future studies that include the same variable and the same population in order to create a larger sample for analysis.

More details about each portion of the study are included below:

Assessment

There will be one pre-test prior to the interventions, and two post-tests after the children have participated in gymnastics or fine motor skills group.

A standardized assessment tool called the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) short form will be used to measure gross and fine motor proficiency at pre-test and post-tests. This test has 8 subsets:

- Fine Motor Precision—2 items (drawing lines through paths-crooked, folding paper)
- Fine Motor Integration—2 items (copying a star, copying a square)
- Manual Dexterity—1 item (transferring pennies)
- Bilateral Coordination—2 items (tapping foot and fingers-same side synchronized, jumping in place- same side synchronized)
- Balance—2 items (walking forward on a line, standing on one leg on a balance beam)
- Running Speed and Agility— 1 item (one-legged stationary hop)
- Upper-Limb Coordination—2 items (dropping and catching a ball-both hands, dribbling a ball-alternating hands)
- Strength—2 items (knee push-ups or full push-ups, sit-ups)

Static balance

Static balance section of The Movement Assessment Battery for Children- Second edition will be used to measure the participants' static balance. Participants will be asked to stand on one leg on a flat surface, lift the free leg, and keep it in any position as long as it is off the floor for up to 30 seconds. The hands are held freely at the sides while performing the test. Both right and left leg will be tested. Each child will perform the test twice for each leg. The time will be recorded, but the best time for each leg will be kept and used to analyze data. Moving the standing foot, heel, or toes from its original place, touching the floor with the free foot, or winding/hooking the free leg around the standing leg will end the test.

Dynamic balance

2 parts of dynamic balance section of The Movement Assessment Battery for Children-Second edition will be used to measure the participants' dynamic balance. For part 1 the participants will be asked to walk on a 4.5 m straight line taped on the floor. The child is supposed to either do 15 steps on the line, or walk to the end of the line, whichever comes first. Number of correct consecutive steps the child takes from the beginning of the line will be recorded without leaving a space between toe and heel, stepping off the line, touching the floor with the free foot in order to regain balance, or readjusting the foot after it has been placed on the line. For part 2 the participants will be asked to do 5 consecutive, continuous forward jumps from mat to mat. Each child will perform each part of the test twice, but the best results will be kept and used to analyze data. Jumps will be counted if they are done without landing on or outside the boundary lines of the mats, stepping from mat to mat, extreme loss of balance/falling, putting hands on the floor, jumping more than once on a mat, and adjusting foot position between jumps.

Risks and benefits:

Your child's participation in this study does not pose any risk that differs from what they would normally encounter in daily life. All physical activities/ motor skills are similar to standard physical education, and sport/recreation camp activities. All fine motor activities are similar to standard arts and crafts classes and camps. As with any physical activity, there is a risk of falling; however, all the equipment for gymnastics intervention is standard physical education equipment and safety is our first priority. All study personnel are trained in First Aid and CPR, and in the event of an injury, the facility's standard emergency procedures will be followed. In the event that your child suffers injury as a direct result of participating in the study, normal legal rules for compensation will apply.

Your child will potentially benefit from this study by receiving valuable gross or fine motor skills instruction and being tested by the research team, which may create more awareness of their gross and fine motor skills. The research findings will also help to shape future programs that will potentially help other children with ASD. Upon request, we may also provide you with a report on your child as to their own personal results.

Are there any consequences for not participating?

No, participation in this research study is completely voluntary. You may withdraw your child from the study at any time by notifying the researchers, and you are not required to provide a reason for doing so. Not participating in this study, or withdrawing your child partway, will have NO penalty to your child's participation in the program and any other future programs. There is no consequence to the study participants for withdrawing; however, if you wish to withdraw your child prior to the end of the study, you will receive feedback of your child's initial results of the assessments, but not the final results.

Withdrawing from the study prior to the end of the study will mean that you and your child will not receive information regarding their final results. If you choose to withdraw your child's data from this study, please inform the researchers before May 2016.

There is a difference between missing a session and withdrawing. If you are going to miss a session, please notify us. You can still attend the rest of the classes if you miss one. If your child does not want to continue participating, even if you want your child to participate, the study will stop.

Confidentiality

The data collected in this study used for current and potentially future research will be secured safely. All information that you and your child provide will be numbered and will not contain names. Overall group results may be published for scientific purposes, but participant identities will remain confidential. Limits of this confidentiality include situations of suspected child abuse, concerns of harm to self or others, or any request for information by court order.

Right to withdraw:

You are free to withdraw your child at any time without penalty. If you choose to withdraw and the data collected from your child is still valuable, we will ask you if you would let us use the data, or if you would like us to destroy the data. You can let us know if you would want us to destroy the data 1 week after withdrawal. If you would like us to destroy the data, any data that has been collected from your child will be destroyed and will not be used in any analyses, publications or future research.

Dissemination:

At your request, you can receive a copy of the results for this study following its completion. You can request a summary of your child's personal results once they have completed their final assessment session.

Questions about the study:

If you have any questions about this study, please contact Shahrzad Pezhman at 905-721-8668-5988 or shahrzad.pezhman@uoit.ca or Dr. Meghann Lloyd at 905- 721-8668 ext. 5308 or meghann.lloyd@uoit.ca. This study has been reviewed and is approved on January 24, 2016 by the University of Ontario Institute of Technology Research Ethics Board (REB #15-074), which is a committee of the university whose goal is to ensure the protection of the rights and welfare of people participating in research. The Board's work is not intended to replace a parent/guardian or child's judgment about what decisions and choices are best for you. If you have any questions about your child's rights as a research participant, complaints or adverse events you may contact the University Of Ontario Institute of Technology Research Ethics Board at 2000 Simcoe ST. N., Oshawa, ON, L1H 7K4, 905-721-8668, ext. 3693 or compliance@uoit.ca

Informed Consent to Participate: Investigating the effectiveness of gymnastics, and fine motor skill interventions on motor skills, static and dynamic balance of children 5-9 with Autism Spectrum Disorder

I, ____,

(Your Name)

the parent/guardian of ____,

(Your Child's Name)

- ☐ **Give consent** to my child's participation in the above study.
- ☐ **Give consent** for my child to be video recorded during the motor skill testing.

I have read and understood the attached information sheet or had the attached information sheet verbally explained to me, and have received a copy of this consent form. I have been fully informed of the details of the study and have had the opportunity to discuss my concerns. I understand that I am free to withdraw my child at any time or not answer questions.

____

Name of Child

______________________________ ______________________________

Name of Parent/Guardian Contact Phone Number

______________________________ ______________________________

Signature of Parent/Guardian Date

Appendix 3: Child Assent Form for Study Participation

Hi Child's name and last name, your parent/guardian has said it is okay for you to be part of my research project; but first I want to ask you if it is okay with you. The reason we are doing this project is to help us understand more about what you like about gymnastics or fine motor classes, and what kind of things we can do so you have more fun when play sports.

We will ask you to show us how you walk, run, jump, and other skills away from all the other kids so no one can see. It will be very short and won't take away from your fun at the program.

You will also get to go to gymnastics or fine motor classes with other children your age this winter to get practice on motor skills through different gymnastics skills, or fine motor activities.

You don't have to participate if you don't want to, and the information you tell us won't be shared with anyone except you and your parents. You can decide to stop the study at any time.

Do you want to participate in this project? ____________ yes ____________ no

Is it okay if we video-tape you when you show us your motor skills?

___________ yes   __________ no

Appendix 4: Social Media Blurb

A research project led by a UOIT Kinesiology student and certified gymnastics coach aims to improve motor skills and balance of children ages 5-9 with Autism Spectrum Disorder (ASD). The children will be randomly assigned into the gymnastics group or fine motor skills group. Children in both groups can improve their motor skills and make new friends. If you are the parent or legal guardian of a child between the ages of 5-9 who like to participate in this FREE 6 week program please contact Shahrzad via: shahrzad.pezhman@uoit.ca or 905-721-8668, ext. 5988. The study will take place Spring 2016 in Oshawa Ontario. Please like or repost this message, to benefit as many children as possible.

Appendix 5: Recruitment Flyer for Study Participation

Appendix 6: Supplemental Information Form for Parents/Guardians

This form includes questions about your child that will help to describe the information we learn through this study and identify factors that may relate to children's rate of progress and development. Please feel free to ask questions if you would like further clarification.

1. Child's name: ____

2. Birth date: __________________ (day, month, and year)

3. What is your child's diagnosis?_____________________________

4. At what age did your child receive their diagnosis? ______________

5. Please indicate the number of siblings your child has and her birth order:
   # Siblings: __________ Birth order: __________

6. Has a doctor or other health care provider told you that there are specific types of physical activity your child should not participate in? If yes, please specify.
   ____

7. Has your child also been diagnosed with any of the following?
   __ Anxiety
   __ Attention Deficit Disorder
   __ Attention Deficit Hyperactivity Disorder
   __ Developmental Delay
   __ Epilepsy
   __ Intellectual Disability
   __Learning Disability
   __ Operational Defiant Disorder
   __ Seizures
   __ Visual Problems
   __ Sensory Integration Disorder

8. Has your child ever received any motor interventions (i.e. physical therapy, occupational therapy)? If yes, please specify from what age and the duration.
   ____

9. Is your child currently receiving any other form of therapy (i.e. speech language, Applied Behaviour Analysis (ABA)-based services, etc.)? If yes, please specify the type and duration.
   ____
   ____

10. Please list any medications your child is currently taking: ______________________________

11. Please self-declare your child's ethnicity using the options below:
(Consistent with Statistics Canada, 2011)

__ Aboriginal	__ Japanese	__ White
__ Arab/ West Asian	__ Korean	__ Undeclared
__ Black	__ Latin American	__ Other:
__ Chinese	__ South Asian	
__ Filipino	__ Southeast Asian	